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LIGHT, HEAT, AND GRAVITATION

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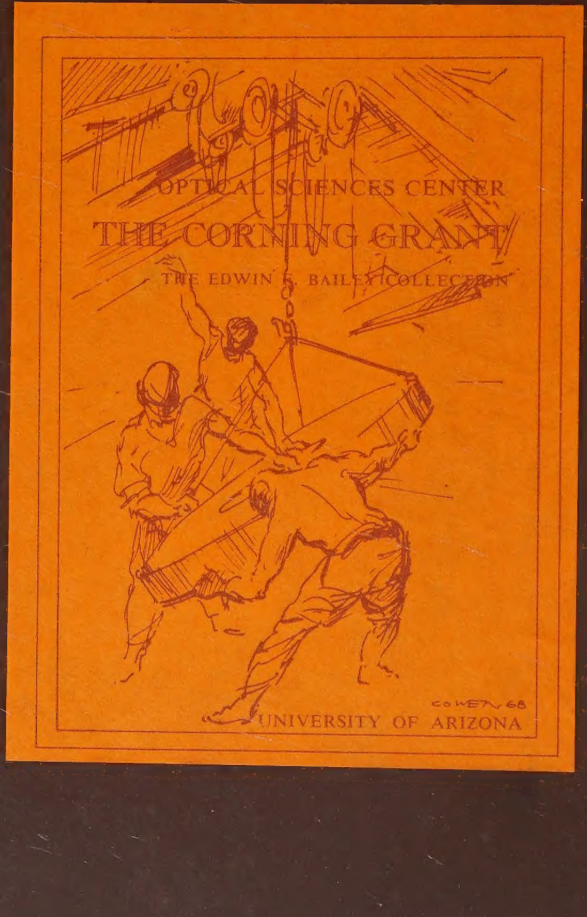

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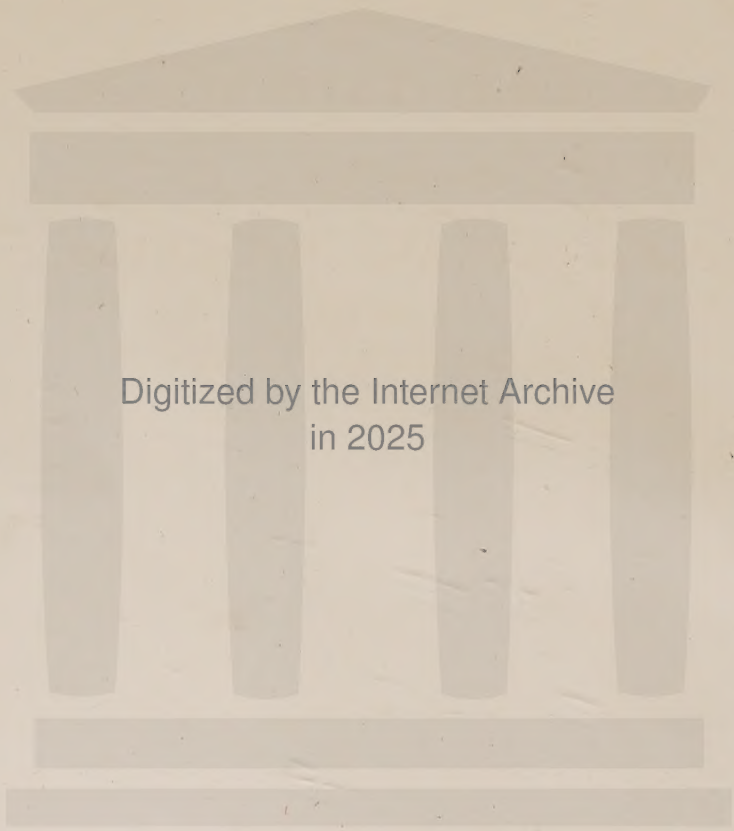
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SOLAR LIGHT AND HEAT:

THE SOURCE AND THE SUPPLY.

GRAVITATION:

WITH EXPLANATIONS OF

PLANETARY AND MOLECULAR FORCES.

BY

ZACHARIAH ALLEN, LL.D.

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PREFACE.

THE present work is a sequel to a publication by the writer, in the year 1851, entitled "The Philosophy of the Mechanics of Nature, and the source of Natural Motive-Power." It is designed to eliminate and arrange in due order the rudimentary facts and principles therein detailed, and to show their harmony with the Laws that control the Material Universe.

This has necessarily involved further researches into the origin of Molecular Forces, of Gravitation, and also of Solar Light and Heat, as immediate sources of Natural Motive-Power.

The results are now respectfully submitted to the reader.

PROVIDENCE, R.I., September, 1879.

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SOLAR LIGHT AND HEAT.

SOLAR LIGHT AND HEAT:

THE SOURCE, AND THE SUPPLY.

CHAPTER I.

INTRODUCTION.

GRAVITATION is commonly defined to be "the force of attraction, by which all portions of matter tend towards each other," leaving the mechanical cause of this force unexplained.

It was not without reason that D'Alembert affirmed, "Philosophers are bewildered by the spectacle of a falling stone." The bewilderment of the illustrious Newton is manifest on referring to the earliest edition of his "Principia," in which he says, "The ultimate particles of matter are endued with inherent forces, or powers of attraction and repulsion." Subsequently, in treating of the universal attraction of gravitation, he says: "Gravity must be caused by an agent acting constantly, and according to certain laws; but whether this agent be material or immaterial, I leave to the imagination of my readers."

In describing the properties of matter, he afterward affirms, as the result of the long-continued

observations of mankind, the following general law of Mechanical Philosophy: —

"Matter at rest is incapable of putting itself in motion, or of stopping itself, or turning aside from a movement in a straight line, when put in motion."

There being no discovered cause of the movements of atoms and bodies on the earth's surface, the ancient Greek philosophers — Empedocles, Epicurus, and Democritus — taught, "The ultimate particles of matter are endued with inherent forces, or powers." Afterward, for nearly a thousand years, this question attracted little attention, being of no immediate profit to mankind, until popularized by the writings of the Latin poet and philosopher, Lucretius.

The doctrines of heathen philosophers, being deemed adverse to those of the Mosaic cosmogony, were opposed by ecclesiastical rulers, who persecuted investigators of physical science. In the year 1600, they burnt Bruno, in Venice, for republishing the doctrines of Lucretius, and imprisoned Galileo, in the year 1663, for teaching the Copernican theory of the revolution of the earth about the sun. With the gradual extension of religious freedom in modern times, philosophers ventured to make researches for the source of natural motive-power. La Place, Descartes, Goethe, Darwin, Spencer, Tyndall, Huxley, and others have published various theories, ascribing

the evolution of molecular actions to self-motive and self-directive powers in matter, generally recognized as Materialism. The popular interest in this theory appears to be due to a desire for freedom of discussion by the philosophers, who claim the same privilege of studying the revelations of the Divine will manifest in the laws that govern the material world, as ecclesiastics enjoy for studying the revelations of the same Divine will in the government of the spiritual world.

The theory of the Newtonian Philosophy, teaching the incapability of lifeless matter to put itself in motion, is discordant with popular chemical and materialistic doctrines of the existence of inherent self-motive and self-directive powers in molecules. This discordance, at the outset, opens the question of the original source of natural motive-power. If, according to the laws of Natural Philosophy, nothing material can put itself in motion, it follows as a logical deduction that the original cause of the motion of matter must be *immaterial.* In tracing out the original source of the movements of all matter in accordance with the primary law of the incapability of matter to move itself, Mechanical Philosophy points, as with uplifted finger, to an immaterial cause, and affirms the words of the Psalmist: "The heavens declare the glory of God, and the firmament showeth his handy work." Consequently, Mechanical Philosophy is based on the original

placing of matter in infinite space by a *Placer*, denoted THEOS, in Greek.[1]

Taking no theories for granted without examination, our investigations will begin with the primary axiom of the Newtonian Philosophy, which affirms

THE INCAPABILITY OF MATTER AT REST TO PUT ITSELF IN MOTION.

The belief of the incapability of matter to move itself is confirmed only by negative proof, because there is no well-authenticated case on record, from time immemorial, of the self-motion of any matter. Beginning observations in early life, children are so accustomed to find

[1] The present popular question of Materialism does not appear to be based on a denial of the pre-existence of a Placer, or THEOS, but on the mode of the original placing of atoms in the formation of the worlds in the heavens, and of plants and animals on earth, denoted "Evolution." Zealous materialists even profess extraordinary reverence toward a Supreme Placer, by proposing to relieve him of "the labor of an artificer, working after the human model" six days and resting the seventh, while making the earth. They suggest the labor-saving plan of primarily endowing atoms with sufficient self-motive and self-directive powers to move spontaneously, and fit themselves to the right places for forming the earth and producing the Evolution of plants and animals, as they apparently do in forming symmetrical crystals. As expressly stated by an eminent materialist in a sensational address delivered at Belfast, he desires "the right of free discussion, claimed and sustained through tribulation and anguish, inflicted and endured in darker times than ours, but always resulting in immortal victories, which Physical Science has won for the race." He continues:—

"The human mind, with the yearnings of a pilgrim for his distant home, recurs to the mystery from which it has emerged, so as to give unity to thought and faith. When this is done, without intolerance and bigotry, then, casting aside all the restrictions on discussions of materialism, I affirm this will be the field for the noblest exercise of the faculties of man." "I tell you, finally, Science claims the right of search.

their playthings remaining at rest where they are placed, that if found elsewhere they ask, "Who moved them?" with the conviction that they could not have moved themselves. Whenever any portion of matter is seen in motion, some external cause of motion is looked for. From generation to generation, these observations of the inertness of matter are so uniformly confirmed, without a single instance to the contrary, that the doctrine of the *inertness* of matter, and of its incapability to turn aside from a movement in a straight line, or to stop itself, is adopted as an axiom of Mechanical Philosophy, for the same reason that the axiom of its incapability to put itself in motion is adopted, — a lack of proof to the contrary. To admit the existence of self-directive powers in matter, would be equivalent to admitting that molecules have volitions and wills of their own.

The stoppage of bodies in motion is always the result of a transfer of the motion to other bodies; for an impulse of mechanical force is as indestructible as the matter to which it is imparted.

The theories of Lucretius and Bruno, of Darwin and Spencer, may be wrong. Here I should agree with you; deeming it, indeed, certain that these theories will undergo modifications. But the point is, whether right or wrong, we ask the freedom to discuss them." "It is by an inscrutable mystery that life is developed, species differentiated, and mind unfolded. In fact, the whole process of Evolution is the manifestation of a power absolutely inscrutable to the intellect of man. As little in our day, as in the days of Job, can man by searching find out this power. There is, you will observe, no very rank materialism here."—*Tyndall's Belfast Address.*

Bodies put in motion in free space continue to move; and in limited space they move until they transfer the action they receive to other matter. For this reason the axiom is adopted, that "action and reaction are equal, and in opposite directions," representing simply the transfer of an impulse.

The ever onward and straight progressive motion of matter, in transmitting mechanical action in free space, is manifested by light from the remotest visible stars; which travels continuously in a straight line during a thousand years or more, before reaching the earth. The continuous progression of impulses imparted to passive matter is sportively verified by children, in setting on end a row of bricks, or blocks, to fall successively one on another. After thus testing, on a small scale, the incapability of matter put in motion to stop itself, the youthful experimenter is impressed with the conviction that an impulse imparted by a touch of the finger would continue travelling around the world and come back to his finger, were it practicable to extend the row of bricks sufficiently.

A tidal wave, raised by an earthquake on the coast of Japan, as stated by Professor Bache, continued steadily progressing across the broad Pacific Ocean, and finally dashed against the coast of America.

The regular diffusion of an impulse of mechanical force is also practically learned by casting

pebbles on the mirror-like surface of a calm lake. The action is diffused in every direction from the central point, in wave rings, that continue enlarging successively, until the original impulse imparted by the hand to the pebble spreads to all the surrounding shores. These illustrations serve to show that there is no limitation to the diffusion of an impulse; as is tested on a sublime scale by the infinite extent of the transmission of gravitating force and light throughout infinite space. These facts, and all other knowledge of the external world, being obtained by the instrumentality of the nerves of sensation, there is consequently

SLOW PROGRESS OF SCIENCE BY EXPERIMENTAL INVESTIGATION.

In Europe, the earliest attempts to learn the properties of matter were made with crucibles and alembics, excited by heat to develop reactions. So fearful were superstitious people of the existence of mysterious powers and evil spirits in peculiar kinds of substances, that experimenters were obliged to work in secret places to find out the real properties of matter. So occult appeared the causes of the behavior of molecules toward each other in uniting interchangeably, and separating, that this new science was denoted "Alchemy," from the Arabic KIMIA, a mystery.[1]

[1] Through Arabia and Egypt most of the original mathematical and chemical sciences of the people of Asia were introduced into Greece

BEGINNING OF A REFORM IN THE SYSTEM AND STUDY OF PHYSICAL SCIENCE.

To check the torrent of popular delusion and belief in imponderable agents of Nature, and of self-directive powers in lifeless matter, the philosopher Bacon took a bold stand, by publishing a

and Rome. The alchemists long labored to render copper, tin, and zinc so freely movable by melting in crucibles as to bring forth hybrid species, including the precious metals, gold and silver.

A Treatise on Alchemy, published in 1591, and "dedicated to the Queen of England by permission," allures the reader to learn "The perfectest way concerning the right means of making the philosopher's stone, *aurum potabile*, and other useful arts,"—all written in poetical stanzas, describing "the twelve gates of entrance to be passed through to arrive at these mysteries." Such a work, published under royal patronage, shows the rude and superstitious state of physical science less than three hundred years ago.

The liquid distilled from the dripping beaks of alembics containing wine was supposed to be "the Elixir of life," and was called by French alchemists *Eau de vie;* but posterity have realized that it has proved to myriads the water of death.

When the French experimenters set afloat two magnets on pieces of cork in a basin of water, and saw them sail toward each other and join together, they gave to them the name of "*aimants*"—lovers—as descriptive of their mutual affection.

In like manner the alchemists, or chemists, in modern phraseology, unable to comprehend the phenomena of heat, light, and electricity, ascribed them to "three imponderable agents of Nature;" to each of which they gave the same name as to the several effects produced by them; thus confusedly blending ideas of the causes and of the effects of the action denoted heat, light, and electricity. This erroneous system is still continued. When a child asks the cause of the beautiful pencillings of glittering frost on the window-panes in a wintry morning, representing fern-leaves and fanciful figures, the answer to this early philosophical inquiry commonly ascribes the work to "Jack Frost;" who is ever afterward remembered as one of the mysterious wonder-working "Agents of Nature."

A belief in the existence of supernatural agents, also, is early impressed on youthful minds by fairy tales, and by ascribing mysterious powers to amulets and rings. In the witch scene, in "Macbeth," Shakes-

work entitled "Novum Organum," or a new systematic organization of physical science, based on facts and reasoning from analogy.

The patient and careful labor requisite for carrying out this inductive system, from one verified fact to another, dispels all romance in the pursuit of physical science, and reduces it to a mathematical precision very distasteful to the ardent and speculative spirit of the age.

With no inducement of pecuniary profit to tempt students to a laborious course of original scientific investigations, few can afford the sacrifice; and most prefer to imagine, rather than to work. Thousands indulge in physical speculations, where one is found plodding slowly by practical verifications. The imaginative Goethe wrote on Materialism, commencing with the apology, that "any theory of the cause of movements of matter is better than none."

peare represents popular delusions and beliefs in the existence of mysterious powers in the various substances added to the bubbling caldron. Romances continue to fascinate the lively imagination of childhood, leaving their impress in after life, and preparing the popular mind for believing in spiritual communications, clairvoyance, and supernatural powers. So strong was the hold of this popular belief in former days, that grave ecclesiastics, legislators, and judges established and executed laws for inflicting the punishment of imprisonment and death on persons accused of "sorcery and witchcraft." Thousands have been imprisoned and put to death in Europe for alleged communications with evil spirits; and even the stern Puritans of Massachusetts hung numerous women and men for witchcraft.

All these pernicious results and superstitious fears of evil spirits and supernatural powers are dispelled by the study of the exact facts of Natural Philosophy, which demonstrates the passiveness of all matter, and its subjection to material and mechanical laws.

Impatient of the slow progress in discovering the cause of the movements of molecules toward and from one another, an excellent chemist — Professor Graham — boldly came forward to settle the popular chemical theory of the existence of inherent self-motive power in molecules, by joining issue with the mechanical theory of the incapability of matter to move itself. He asks earnestly, "Which shall yield to the other?"[1]

With the hope of harmonizing this discord between the two sister sciences of chemistry and mechanics, the writer of these pages devoted much labor to researches on this subject, and published the result, in the year 1851, in a treatise entitled, "The Philosophy of the Mechanics of Nature, and of the Source and Modes of Transmission of Natural Motive Power."[2]

Failing to discover any self-originating cause of motion in terrestrial matter, the writer was led on to take a broader view of the passive functions of our planet, as subordinate to universal laws, and as being a minute working-part of the mechanism of the solar system. In the continual swift-revolving movements of more than one hundred and fifty great planets and asteroids, there is an actually existing momentum, or moving force, amply sufficient to sustain all the relative movements of terrestrial molecules and bodies, and requiring only to be traced out in accordance with universal

[1] Graham's Chemistry. [2] D. Appleton & Co., New York.

laws of transmission through the medium of a universally diffused electric ether. With this great fact before us, of the existence of an infinite extent of natural motive-power in continual action in the heavens, we may well discard all speculations on the existence of inherent self-motive and self-directive powers in lifeless matter, and also about the mode in which the solar system was originally created, and plants and animals placed on our planet; and turn our attention strictly to the potentialities of this motive force.

CHAPTER II.

MOMENTUM OF THE PLANETS A SOURCE OF NATURAL MOTIVE-POWER. — ESTIMATES OF PLANETARY FORCES, MAGNITUDES, AND REVOLUTIONS.

> "Look downward on that Globe, whose hither side,
> With light from hence, though but reflected, shines :
> That place is earth, the seat of man."
>
> *Milton's Paradise Lost.*

MECHANICAL Philosophy, like the angel described by Milton, lifts the student to the central orb of the solar system, "the gate of light," to take a preliminary view of the sublime extent of the universe.

To an observer of our planet, stationed on the planet Venus, the reflection of sunshine renders the apparently dull surface of the earth as brilliant as Venus appears to us in the evening sky. The magnitude of our earth, great and important as it appears to us, is only $\frac{1}{1400}$ part of the magnitude of Jupiter, and less than $\frac{1}{100}$ part of the magnitude of the nearly invisible planet Neptune, the existence of which was discovered only a few years ago.

So numerous are the stellar suns to other systems of worlds in infinite space, that the first sight of their glorious splendor, revealed by a

modern telescope, overwhelms the observer with awe and admiration.

Guillemin, an eminent writer on astronomy, estimates that seventy-seven millions of stellar suns are visible from our earth by means of improved modern telescopes. Allowing to each of these stellar suns the same number of worlds that revolve about our sun, it is calculated that ten thousand millions of planetary worlds exist within the range of telescopic vision from our earth; and are therefore included in "our cluster" of worlds in the heavens. This visible portion of the material universe suggests the occupancy of infinite space by similar clusters beyond clusters, in boundless progression. That our sun and the distant stellar suns are in rapid motion is verified by observations of astronomers, who have discovered that some of them are actually revolving about one another in double systems, like the great stellar sun Sirius; which is more than twelve hundred fold greater than our sun.

The similarity of the construction of the other worlds in the heavens, and the prevalence of the same universal laws governing their existence, are manifest by the recent revelations of the spectrum analysis. The neighboring planet Mars is so distinctly seen by modern telescopes, that the outlines of a geographical map of it have been delineated, showing continents, oceans, and snow-white polar regions. These observa-

tions confirm a belief that all the planetary worlds are adapted for abodes of intelligences, and for promoting the happiness of sentient beings.

The original placing of the revolving worlds in the heavens, being ascribed by Mechanical Philosophy to an immaterial First Cause, is beyond the reach of physical investigation; which therefore begins with the manifest facts attending their actual existence and movements. It is not necessary for an engineer to know who invented the steam-engine, or how and when it was originally made, before he can proceed to study the general principles that govern its operation. Its actual construction and functions reveal the science and ability of the maker, and his purpose.

The mechanism of the solar system being far beyond the possibility of immediate examination, Sir John Herschel points out to students "the surest guide for direction, by reasoning from analogy of celestial to terrestrial mechanics;" both being alike governed by universal laws. Professor Proctor says: "Terrestrial analogies afford a very sure guide in the midst of the many perplexities, which the study of the worlds around us presents to our contemplation." After recognizing the law that matter put in motion cannot stop itself, the student realizes that the vast masses of the revolving planets serve as balance-wheels to retain

and equalize the transmission of the impulses originally imparted to them, with amply sufficient power, if properly transferred, to produce all the relative movements and states of rest of terrestrial matter.

ESTIMATE OF PLANETARY FORCE.

The extent of motive-power embodied in a mass of matter in motion is calculated by multiplying the velocity in feet per minute by the weight in pounds. The resultant force is denoted *momentum*, and is expressed in "foot-pounds."

The weight of the mass of the earth is estimated at 6,069,005,178,000,000,000,000 tons, including the weight of the atmosphere.[1]

The orbital velocity of the globe of the earth being 19 miles per second, or 6,019,200 feet per minute, the orbital momentum of the earth is therefore about 2,000,000,000,000,000,000,000,000,000 (two octillions) horse-power, according to the American and French system of numeration.[2]

In addition, there is also to be estimated the momentum of the rotating force of the globe of the earth on its axis, 24,000 miles in circumference, with

[1] Guillemin's Astronomy, p. 103.

[2] It appears that the English system of numeration estimates 1,000,000,000,000,000 (one million millions) as one *billion*, and each higher denomination a *million* times the one preceding.

The French and American system estimates 1,000,000,000 (one thousand millions) as one *billion*, and each higher denomination a *thousand* times the one preceding.

a surface velocity of more than 15 miles per minute at the equator.

It is to be remembered that our earth is one of the smaller planets, being only $\frac{1}{1400}$ part of the magnitude of Jupiter, and that there are more than one hundred and fifty planets and asteroids all swiftly revolving as working parts of the mechanism of the solar system.

The vast planet Jupiter, 89,000 miles in diameter, rotates in 10½ hours, and has a surface velocity of nearly 450 miles per minute.

The annexed table shows the comparative magnitude of our earth and the other planets of the solar system, and also their relative velocities: —

TABLE OF THE MAGNITUDES AND VELOCITIES OF THE SUN AND PLANETS.

Planets.	Diameters.	Relative Magnitudes as compared with the Earth.	Orbital Velocity.	Distance from Sun.
Mercury	3,089 miles.	$\frac{1}{17}$ of magnitude of the earth.	29 miles per second.	35,392,000 miles.
Venus	7,100 „	Equal „ „ „	22 „ „	66,134,000 „
Earth	8,000 „	*Unit of comparison.*	19 „ „	93,321,000 „
Mars	4,115 „	$\frac{1}{7}$ of magnitude of the earth.	16 „ „	139,311,000 „
Asteroids	30 to 500 „	Various magnitudes.	12 „ „	Various.
Jupiter	89,000 „	1,400 fold greater than the earth.	8 „ „	475,692,000 „
Saturn	70,000 „	1,000 „ „ „ „	5 „ „	872,137,000 „
Uranus	34,000 „	83 „ „ „ „	4 „ „	1,753,869,000 „
Neptune	37,000 „	105 „ „ „ „	2½ „ „	2,745,998,000 „
The Sun	887,000 „	1,300,000 „ „ „ „	4¼ estimated.	Central Orb.
	The Sun is more than seven hundred fold greater than all the combined planets.			

The surface velocity of the rotation of the sun is about 1¼ miles per second.

The name of "planet" is borrowed from the Latin word PLANO, — *I wander*. The planets are systematic wanderers, continually circling about a common centre in harmonious order, and with velocities diminished in proportion to their increased distances therefrom.

The greatest comparative quantity of matter employed in the construction of a steam-engine is embodied in the ponderous balance-wheel; in the momentum of which the impulses imparted are retained, to be uniformly transmitted. For the same reason a great quantity of matter is embodied in the revolving orbs of the planets, to receive and continuously transmit the impulses primarily imparted to them as the source of the natural motive-power, transferred continually by the medium of a universal ether; which serves as a substitute for connecting bands and shaftings in the mechanism of the solar system.

POPULAR IDEAS OF THE REVOLVING MOVEMENTS OF THE PLANETS.

The supposition generally prevails that the only design of the rotation of the earth is to cause the day and night to succeed each other, for affording timely rest for animal refreshment; and that the yearly orbital revolutions are designed only to bring about changes of the seasons, with seedtime and harvest.

Pythagoras fancifully suggested that the movements of the planets produce harmonious sounds to time their marches through the sky, with tones varying in accordance with their greater distances from the sun. Hence originated the theory of "the music of the spheres." Job refers to this idea in the words, "When the morning stars sang together, and all the sons of God shouted for joy." Shakespeare recurs to this theory in "The Merchant of Venice," — "There 's not an orb of all which thou beholdest, that does not in its movement like an angel sing." Addison describes the stars, "For ever singing as they shine."

The same electric medium, that transmits vibrations as light, transmits musical sounds, as tested by telegraph wires connected with telephones; and were the nerves of the ear as delicately sensitive as the nerves of the eye, we might hear, as well as see, the heavenly orbs timing their marches by harmonious measures through the sky.

UTILIZATION OF AN INVISIBLE MEDIUM FOR TRANSMITTING MECHANICAL ACTION.

Two thousand years before Newton suggested the necessity of a connecting material medium between the heavenly bodies, to hold them together in circling orbits, the poet Homer, witnessing the glittering links of lightning suspended

between the dark clouds and the earth, expressed this idea in Jupiter's address to the council of gods: —

> "Let down our golden, everlasting chain,
> Whose strong embrace holds heaven to earth and main."[1]

The ancient philosophers taught the existence of an etherial medium occupying the space intervening between the grosser particles of bodies; and for many ages after the doctrine was accepted, and transmitted to later times as "the theory of *phlogiston;*" — a term derived from the Greek PHLOGOS, *flame.* With modifications, the doctrine of a universal ether still prevails, and is confirmed by the conclusions of the most acute observers, as well as those of the most profound intellects of our day.

As to the nature of this ether, all we know is its capability of transmitting the slightest impulse of mechanical force. Beyond this, we must make the same acknowledgment of the limitation of human powers of perception as Faraday makes in reference to the essential nature of all kinds of matter, when he affirms, "*All we know of matter is its power of transmitting action;*" or, as does another eminent writer, in treating of molecules as merely "*centres of forces,*" admitting them to be too minute to be distinctly recognized.

Passing by, then, all speculations as to the nature and constitution of the universal ether, it is

[1] Iliad, book viii.

sufficient to recognize the fact, that it is so pre-eminently sensitive to, and active in, the transmission of what men call electric, magnetic, and galvanic force, that we are well warranted in calling it "electric ether," even if it be not in its essence what men call the "electric fluid" itself.

Facts demonstrate that the impulse from the hand, applied to turn the crank of a Holtz electrical machine, disturbs and puts in motion a material medium, that transmits the impulses it receives in various ways, even to representing a little world in miniature. A dawning light appears, rivalling the splendor of the rising sun. A breeze from a pointed wire on the conductor transmits sufficient force to turn a little paper windmill, and light paper-figures of men and women are excited to rise up from repose and dance. Rose-colored coruscations of the aurora and meteoric shooting-stars are represented in a glass tube exhausted of air. Flashes like lightning, and sounds as of thunder, are produced by the discharge of a coated jar, and combustibles are fired. Particles of solid bodies are scattered into vapors, and those of water decomposed and reunited, representing chemical action. Even the mechanical functions of the living human body are excited by the impulse. For when the machine puts in motion the electric ether through the five different arrangements of sensorial nerves, so as to reach the tribunal of human intelligence

in the brain, the effect of the mechanical action imparted by the hand to the cylinder is recognized by as many different names as there are lines of telegraphic nerves leading to the brain. An identical electro-mechanical action transmitted through the nerves of the eyes is denoted LIGHT; through the nerves of feeling, HEAT; through the nerves of the nose, ODOR; through the nerves of the tongue, TASTE; and through the nerves of the ear, SOUND.

CHAPTER III.

ALL SPACE NOT OCCUPIED BY OTHER MATTER IS OCCUPIED BY A UNIVERSALLY DIFFUSED AND INVISIBLE ELECTRIC MEDIUM.

WHILE it is popularly supposed that a *vacuum* results from the exhaustion of the air beneath a glass bell by an air-pump, the following experiment will show that this supposed *vacuum* is pervaded by the electric ether: —

A brass knob connected with a conducting wire is arranged above another similar knob, as shown in Fig. 1; and the excitation from an electrical machine is used to induce a current through the void space in the jar. On turning the crank of the machine, a cascade of lambent flames appears pouring down from the upper knob.

Fig. 1.

If a long glass tube be used, the coruscations are extended in rose-colored flashes, resembling those of the aurora borealis, above the earth's atmosphere.

By admitting a little air into the tube, to represent the partial exhaustion of the air in the upper regions of the earth's atmosphere, the electric discharge is impeded, and condensed into balls of fire, resembling meteors, or shooting-stars, with their minute trains.

These experiments show that there is really no void space between the worlds of matter in the heavens, and that there is a connecting material medium between them, capable of transmitting mechanical action and reaction with the velocity of light, as manifest in the continual action of sunshine and of so-called gravitation, between all the heavenly bodies.

THE MINUTE SPACES BETWEEN ATOMS PERVADED BY THE ELECTRIC ETHER.

The reciprocal action between magnets in space exhausted of air, denoted a *vacuum*, and between the component molecules of all solid and liquid bodies, denoted "molecular force," manifests the existence of a material medium between them, capable of transmitting impulses. Every disturbance of the relative positions of adjacent bodies, or molecules, simultaneously disturbs and puts in motion the electric medium

intervening between them, as is manifest by striking two stones together, by abrasion of steel by a flint or emery-wheel, and by crushing pieces of quartz, feldspar, and even dry lumps of sugar in an iron mortar, whereby the interior appears filled with electric sparks.

Even the aëriform particles of the atmosphere manifest similar electric excitation when mechanically compressed beneath a piston in a small cylinder, whereby tinder may be ignited; as was often done before the invention of friction matches.

On beholding the bright flashes within a cleft of dry wood suddenly laid open by his axe, a pioneer in a Western forest once paused to express to the writer his belief that "fire exists in wood, and comes out in burning."

The ready permeation by the electric ether even of non-conducting glass, is shown by holding a plate of glass between an excited conductor, A (Fig. 2), and the knob of a conducting wire, B. As exhibited in the drawing, every electric spark appears to pass instantaneously through the plate of glass, as if it were perforated by it.

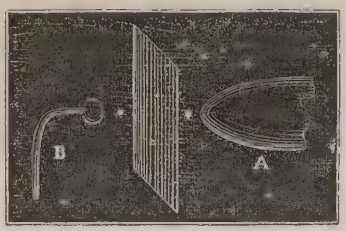

Fig. 2.

This experiment illustrates the transmission of electro-mechanical action through the electric

ether pervading the particles of transparent bodies, and confirms the identity of solar light and of electric action; and shows that the spaces between the particles of glass are occupied by the electric ether as a medium of communication.

ORIGINAL SCIENTIFIC DISCOVERY OF ELECTRIC EXCITATION.

The ancient Greek philosophers appear to have been the earliest to notice and record the existence of the universal electric medium, and the mode of its excitation in obedience to mechanical impulses imparted to it. On rubbing pieces of amber, bright sparks appeared; and for this reason the Greeks gave the descriptive name of ELEKTRON, *sunshiny*, to this peculiar resinous substance. This term is borrowed from another Greek word, ELEKTŌR; which is defined, "The *sunshine* that excites men to rise from their beds." The English term, "electricity," derived from this Greek word, therefore, literally means "sunshine."

Pythagoras taught that this same ELECTŌR, or sunshine, is manifest in the splendor of lightning; the heat, or burning power, of which is denoted KERAUNOS in the Greek.

Hippocrates, another Greek philosopher, taught "the existence of a universally diffused ether, which in motion constitutes elementary fire, and silently actuates and animates all things."

Still another Greek philosopher, Galen, taught the subserviency of the electric ether as a general medium of communication between material bodies and the immaterial mind, or soul; and even between mind and mind. He foreshadowed modern discoveries in electro-telegraphy in the following memorable words: —

"Admitting the soul to be immaterial, it hath for its immediate tunicle a surrounding ether, or luciform vehicle; by the intervention whereof it moveth bodies, and is reciprocally reacted upon therefrom. This tunicle of the soul, whether it be called pure ether, luciform vehicle, or animal spirit, seemeth to be that which is moved by the volitions to act on the grosser organs, or muscles, as may be determined by the soul; from which the ether immediately receives impulses, and in which the original moving power truly and appropriately resides."

This supposition of an old philosopher appears to be verified by every step of progress towards the mysterious connection between the immaterial mind and the material mechanism in which it is temporarily embodied. It is certainly a beautiful as well as philosophical idea, to imagine the mind, or spirit, enthroned in "a pure ether," — as if too refined for immediate contact with the gross matter of the brain.

This "pure ether, or luciform vehicle," is now artificially employed in electric telegraphs for

holding communications between mind and mind all over the earth; and is naturally employed in transmitting the twinkling telegraphic communications which pass between the distant stars and the earth.

HEAT AND LIGHT TRANSMITTED BY MECHANICAL IMPULSES IMPARTED TO THE ELECTRIC ETHER.

Every impulse that moves portions of matter disturbs the surrounding electric medium, and is transmitted to the human brain through the conducting nerves, to produce sensations of heat and light when sufficiently intense. Otto Guericke (the inventor of the air-pump) and Volta took the lead in experimentally verifying the fact, that every movement of one body near another disturbs and puts in motion the electric ether in both bodies, diffusing the action in various ways; as by vibrating undulations of the electric medium to reach the brain through the sensorial nerves, recognized as the sensations of *light* and *heat*, and by movements of light bodies, such as pith-balls, flexible threads, or hairs, gold leaf, &c. From the ready movement of all such light bodies used as tests of electric excitation, they are descriptively denoted ELECTROSCOPES; from the Greek words ELEKTŌR, *solar action*, and SKOPEŌ, *I behold*.

A simple mode of verifying electric disturbances by the movements of bodies was

originally adopted by moving two metallic plates, held by insulating glass handles (Fig. 3), which, after contact and separation, excite movements of electroscopes.

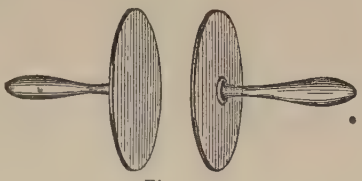

Fig. 3.

To intensify the excitation of the plate, a cake of sealing wax, C, excited by friction with fur, is commonly used, as represented by Fig. 4. Holding the plate D by the insulating glass handle K, and reaching the finger toward the metallic knob N, a spark is seen to leap through the air from N to the finger, when the plate D is brought near and in contact with C; on lifting the plate and again bringing the finger toward N, a similar bright spark leaps back to the plate.

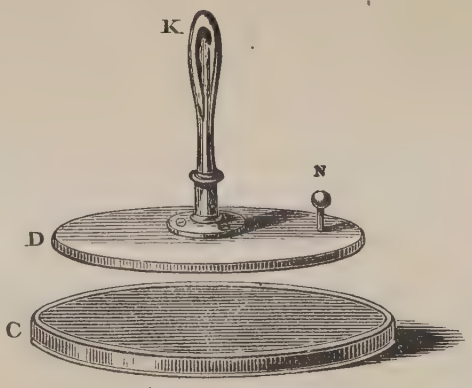

Fig. 4.

This simple apparatus, by the alternate movement of the upper plate toward and from the lower plate, produces such dazzling sparks, that the original inventor gave to it the name of ELECTROPHORUS; from ELEKTŌR, *sunshine*, and PHOREO, *I bring*.

This experiment practically demonstrates that mechanical action, applied to move bodies toward and from one another, is capable of producing light and heat, identical with *sunshine.*

While the upper plate rests on the lower plate, the electric ether remains in an electrostatic condition in the plates, developing no action until they are moved asunder, when a spark is obtainable by lifting the upper plate. This ever-ready spark may be conveniently employed for kindling gas-lights, by directing it through the jet of gas.[1]

The most regular and systematic mode of moving bodies, for disturbing and putting in motion the electric medium, is by axial and orbital revolutions opposite to each other, — as naturally employed in the daily and annual revolutions of the planets of the solar system, and in the rotations of artificial electric and magneto-electric machines.

Every impulse of mechanical force applied to rotate an inductive electric machine, or a magneto-electric machine, develops the excitation denoted "electric light and heat," — the equivalent of sunshine. The mechanical force of waterfalls, of the winds and waves of the sea, and

[1] The "*static*" condition of forces is commonly considered to be their state of absolute rest; but so far is this idea from being true, that, on the contrary, a double extent of oppositely directed impulses is requisite for the counterbalancing of forces. When any disturbance of the equilibrium is produced, then the predominant force develops a resultant dynamic action. To these resultant forces may be traced most if not all of the relative movements of terrestrial matter, as will hereafter more fully appear.

animal motive-power, may all be converted into electrical light and heat by being applied to turn magneto-electric machines, — such as are used in modern lighthouses to illumine dark seas and headlands with the splendor of sunshine. The mechanical force of the rise and fall of the tides on sea-coasts is adequate to rotate a sufficient number of magneto-electric machines to illuminate all the bordering shores; and that of the waters of Niagara to illumine the great cities of the world.

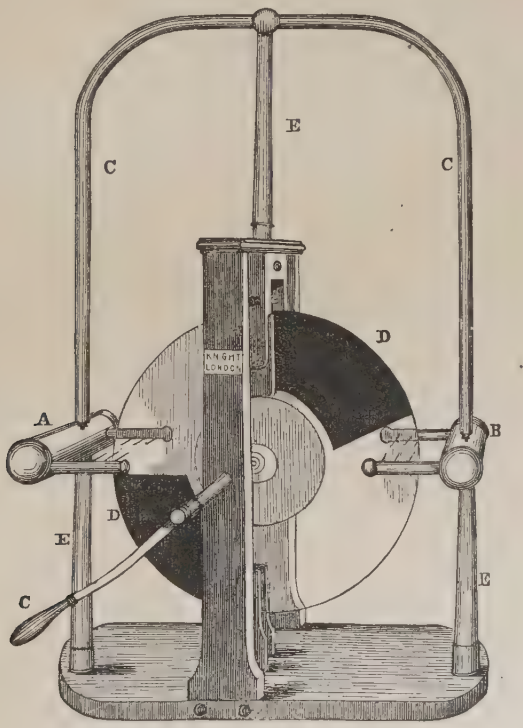

Fig. 5.

The actual contact and friction of the surfaces of all bodies excite heat and light, as is familiarly known; and a similar contact and friction of a rubber on the surface of rotated cylinders of glass, sulphur, and resinous substances, were originally employed for exciting electricity, as represented by Fig. 5. But the most effective kind of electrical machine is the invention of Professor Holtz, Fig. 6; with one glass plate revolving opposite to another, without contact, and with a space of air intervening between them, as between the earth and the sun. Rows of pointed wires are arranged in the usual way to intercept and conduct away the electric currents. By means of this machine, bright electric flashes are seen to pass nearly two feet through the air, in a zigzag course.

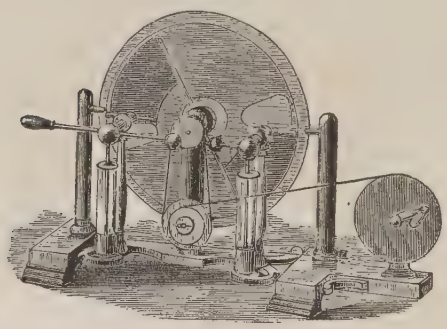

Fig. 6.

Another efficient mode of disturbing and putting in motion the electric ether in currents was originally devised by Professor Faraday, who had recourse to the use of excited magnets to induce excitation of more powerful electric action. He used a spiral coil of wire to be slipped down over the pole of a magnet, as shown in Fig. 7,

with the ends of the wire connected with a gold-leaf electroscope, D. When the coil E is slipped down over the pole of a horse-shoe magnet, S, the electric ether pervading the spiral coil A, being put in motion through the circuit of the wire A B E, traverses the strip of gold-leaf between the two vertical poles of another magnet, N S, whereby the flexible gold-leaf is moved toward the spectator during the continued descent of the spiral coil A. An opposite deflection of the gold-leaf occurs on lifting and taking away the spiral coil. By alternately approaching and withdrawing the spiral coil of conducting wire, corresponding electric surges move back and forth in tidal waves, and the gold-leaf swings back and forth correspondingly.

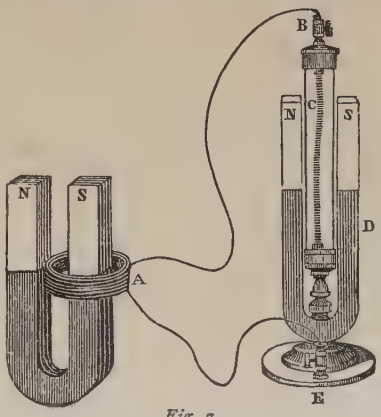

Fig. 7.

These movements, being made slowly, are less effective than when made rapidly, by rotating the spiral coils inclosing a piece of iron bended to the same horse-shoe form, as represented in Fig. 8. The iron is rendered magnetic when the two ends pass by the opposite poles of a permanent horse-shoe steel magnet, N. A wheel and band, W, are used to increase the velocity

of revolutions of the coils inclosing the soft iron bar B.

Two flexible wires pressing against the arbors serve to break the circuit for an instant, and to change the direction of the alternate currents to a uniform circuit by their adaptations for this purpose.

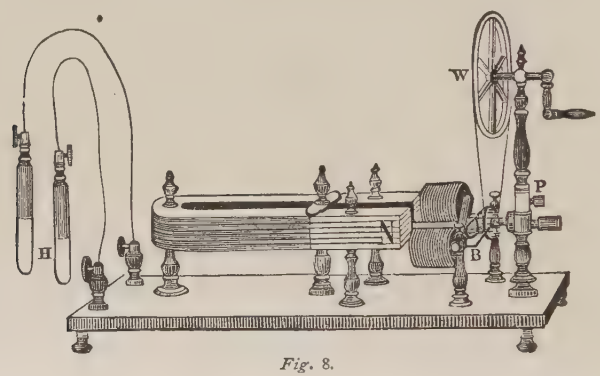

Fig. 8.

The rapidly ebbing and returning electrical surges through the conducting wires, terminated by handles at H, serve to give a rapid succession of electric shocks when held in the hands.

By the instrumentality of these revolving coils and magnets, several thousand changes of direction of electric surges are produced per minute, when numerous magnets are multiplied in the great machines now employed for producing electric light. It is practically found that the most powerful electric excitation is produced by using electro-magnets, formed of bars of soft iron, with electric currents circulating around them through spiral coils of

conducting wires wound in the corkscrew form of a helix. The action of these currents is more powerful than those about permanent steel magnets.

Current changers, or *commutators*, convert vibrations into continuous currents in closed circuits, as previously described.

The swift axial rotations of the planets opposite to the excited globe of the sun, by inducing the continual circulation of electric currents about each one of them, convert them all into powerful electro-magnets. Thus we have a solar system with a vast central electro-magnet, and one hundred and fifty electro-magnets revolving around it, each rotating on its axis. These act and react on each other unceasingly, and with intense power, developing the phenomena of solar light and heat.

THE ROTATION OF ALL BODIES OPPOSITE TO MAGNETS INDUCES CIRCULATING ELECTRIC CURRENTS.

Glass cylinders are used for exhibiting electric excitation in preference to metallic plates, because the particles of this compound substance, like those of amber and other resins, do not allow of the speedy diffusion of the excitation in every direction.

To prove that the rotation of all bodies near magnets induces the disturbance of the electric ether, and the transmission of action thereby, Professor Faraday rotated a copper plate between

the two poles of a horse-shoe magnet, as represented in Fig. 9. The electric circuit is formed by connecting wires, w, w, and a galvanometer is used to indicate the power of the excited current by the deflection of the magnetic needle.[1] Professor Faraday says: "When this copper plate

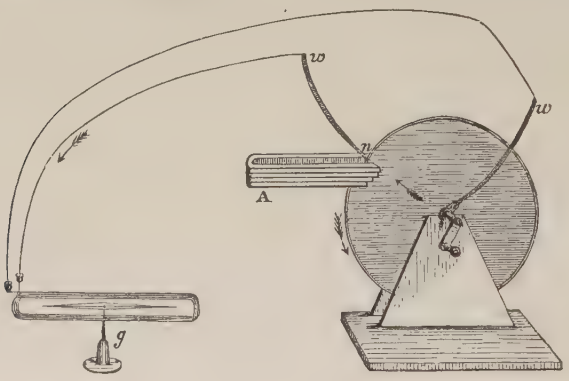

Fig. 9.

was arranged to revolve with its plane at right angles to the dipping-needle, the electric currents circulating from east to west about the earth's surface served as a substitute for those circulating about the poles of the artificial magnet."

Remarking on the results of his experiment, Faraday says: "This affords an instructive contrast with the operation of a common electrical machine. In the one is used a plate of the best non-conducting material, and in the other the most perfect conductor. In the one, insulation is essential; in the other it is fatal. In com-

[1] Faraday's Experimental Researches.

paring the quantities of electricity produced, the rotating metallic plate does not at all fall short of the glass one; for it produces a constant electric current capable of turning a galvanometer needle, which the latter cannot."

The excitation induced by the swift rotation of a metallic plate directly over, or beneath, a compass needle, even with a non-conducting sheet of glass intervening, turns the needle as regularly as if it were fixed on the same axis.

This experiment demonstrates that the circulation of electric currents, artificially produced by the rotation of one body near another, is capable of transmitting mechanical action even through non-conducting glass.

Soon after the publication of Faraday's experiment made with the slow motion imparted by hand, the writer employed water-power to rotate a metallic plate several thousand times per minute. An unexpected result occurred on using a circular disc of soft Russia sheet-iron, when it touched a steel magnet, as represented in Fig. 10.

At the point of contact, the swift rotation of the plate excited a steel-bar magnet to a glowing red heat, and large steel files yielded before the rotating disc of thin sheet-iron, like wax before a flame. The fused particles fell on the floor beneath, while the

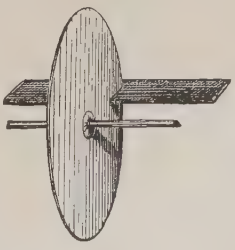

Fig. 10.

smooth edge of the plate remained cool and but slightly abraded.[1]

[1] An account of this experiment was published in 1851, in the "Philosophy of the Mechanics of Nature," p. 310; and recently this experiment has been repeated by Mr. Isaac Reese, of Pittsburgh, Penn. An account of the extraordinary results was given by Professor Hendrick to the American Association for the Advancement of Science, in the year 1875. Mr. Reese used a circular disc of malleable iron of the diameter of forty-two inches, and with a velocity of the circumference nearly five miles per minute. As stated: "Steel bars, hardened and polished, of the diameter of two or three inches, may be cut off simply by the overpowering excitation induced by the swift rotation of a thin circular disc of soft sheet-iron. The best steel was rapidly cut through. Sparks in a steady stream were thrown off, and particles of steel were found melted together in a conical shape beneath the machine. While this fusion of the steel takes place, the disc itself remains but little heated."

The powerful excitation induced by the rotation of one body near another in this experiment, shows the superiority of this method of developing electric excitation to that of Voltaic batteries employed to render a small wire red hot. The velocity of the equatorial surface of the earth, continually rotated opposite the body of the sun, is nearly fourfold swifter than that of the rim of the rotated plate used in the experiment of Mr. Reese.

CHAPTER IV.

THE PERFECT REGULARITY OF THE DAILY ROTATION OF THE EARTH SERVES AS THE STANDARD MEASURE OF TIME, SPACE, WEIGHT, QUANTITY OF MATTER, AND MECHANICAL FORCE.

FOR measuring time, one rotation of the earth on its axis is adopted as the unit standard, denoted a DAY. The minutest subdivision of time is $\frac{1}{86,400}$ part of one rotation of the earth, denoted a SECOND.

The earth turns on its axis three hundred and sixty-six times in the period of one orbital revolution about the sun. While the same spot on the earth's equator passes under a meridian star three hundred and sixty-six times yearly, it passes only 365¼ times under the meridian sun. Nearly one entire day is lost by the circling movement of the earth around the sun, as occurs when a navigator sails from east to west around the world. Consequently, each solar day is twenty-four hours and four minutes long.

A heavy body attached to the end of a rod exactly $39^{\prime\prime},\frac{393}{10,000}$ inches in length, forming a pendulum, will make precisely one swing in the $\frac{1}{86,400}$ part of one rotation of the earth on its axis. All bodies used as material measures of length

being liable to wear, to expansion, and to gradual decomposition, it is established by statute law of Great Britain, that "the length of a pendulum vibrating in the $\frac{1}{86,400}$ part of the daily rotation of the earth, in a vacuum at the sea-level, and in the latitude of London, at the temperature of sixty degrees, shall be resorted to for the reconstruction of the standard brass-measures of the realm, in case of their destruction or loss."

The unvarying velocity of the daily rotation of the earth sustains a correspondingly unvarying excitation of electric currents about it, with consequent uniform electro-magnetic forces of action and reaction between every particle of the mass. The extent of the electro-magnetic force of gravitation consequently represents the quantity of particles in a body, as ascertained by counterpoising weights commonly employed for ascertaining the quantity of matter in articles of merchandise.

The unvarying force of gravitating descent of one pound thirty-three thousand feet in one minute, or thirty-three thousand pounds one foot in one minute, is adopted by engineers as the measure of the power of a work-horse, as estimated in "foot-pounds," and called "one horse-power."

The *foot-pound* is now commonly adopted as a standard unit of all motive-power, even including that of heat employed for operating steam-engines, as tested by Mr. Joules. The precise extent of me-

chanical action requisite to produce the increase of the vibrations of the electric ether pervading the particles of a pound of water, to raise its heat one degree of Fahrenheit's scale, has been ascertained by Meyer and Joules to be the equivalent of seven hundred and seventy-two foot-pounds. Instead of the rotating cylinder of an electrical machine, they had recourse to rotating a little paddle-wheel in a box containing a pound of water at the temperature of thirty-nine degrees of Fahrenheit. In this way, seven hundred and seventy-two foot-pounds have been adopted as "the British unit-standard measure of the increase of one degree of heat in a pound of water;" and on this basis have been made useful comparative estimates as to the economical employment of fuel for developing heat as motive-power.

The vibrations of the ether pervading a bar of steel by the swift rotation of a disc of sheet-iron, as previously described, would probably develop one degree of heat in a pound of water, by a force of seven hundred and seventy-two foot-pounds, were the disc made to rotate against the poles of a horse-shoe magnet partially immersed in the pound of water.

In like manner, the gravitating force of seven hundred and seventy-two foot-pounds may be employed to rotate the cylinder of an inductive electrical machine, to test and measure the intensity of both heat and light by the precise extent of action employed to produce their development.

CHAPTER V.

POPULAR THEORIES AS TO THE SUN.

THE cause of solar excitation is commonly ascribed to the combustion of gases, or other inflammable substances, such as are used for maintaining beacon fires. This theory includes the question of providing a vast quantity of fuel for supplying such a great conflagration. Newton suggested that the occasional visits of comets near the sun might serve for transporting fuel to sustain the waning supply. Others have suggested that meteoric showers, by continually falling on the orb of the sun, might excite it similarly to the pounding of a bar of iron on an anvil; by which process blacksmiths sometimes kindle their forge fires. This theory opens the question, "What Cyclops untiringly wields the meteoric hammers?" The combustion of gases is also suggested; for the existence of hydrogen in the solar orb is indicated by the lines of the spectrum analysis. But the difficulty in the way of this theory is the want of an adequate supply of free molecules of oxygen, of which eight-fold more is requisite than of the hydrogen; with the

resulting product by combustion of nine fold of water. This would finally cover the surface of the sun with a fire-extinguishing ocean, like three fourths of our globe covered by seas. Were the globe of the sun composed of carbon or coal, and surrounded by an atmosphere of oxygen, the combustion would be terminated by absorbing threefold its weight of oxygen, and producing a fire-extinguishing atmosphere of carbonic acid gas; the presence of which, unless there are forest leaves on the sun as on our earth to absorb it, would, when increased to only one fifth of the solar atmosphere, finally extinguish combustion, if that atmosphere is like ours.

In the modern invention of fire-extinguishers, carbonic acid gas in portable cylinders is employed as the most effective check to conflagrations.

An astronomer has calculated that to sustain for a few thousand years the intensity of solar light and heat, would require a quantity of solid coal as great as the bulk of the earth.

As the compression of air and other substances develops heat, some theorists have suggested this cause, but without proposing any mode of compressing the solar atmosphere.

In the "Reported Observations" of the total eclipse of the sun in 1878, President Morton affirms, that "evidences tend to sustain the theory that the sun's heat is maintained by the im-

pact of meteoric matter; and it is possible that the sun's fires may be fed with partly mineral matter, and again for considerable periods with meteorites, highly charged with hydrogen, giving the sun a far-reaching atmosphere of the ignited gas."

Professor Proctor, in recapitulating these theories, says: "By all of them the means of sustaining the solar excitation would in time be exhausted." In referring to the pounding of meteors on the sun as on an anvil, the professor remarks: "All the uproar on our earth would be an absolute quiet compared with this; even including the hideous groanings of earthquakes." To cheer his audience with the hope of not being left in the dark by the last fading glimmer of expiring sunshine, the professor humorously suggests: "Our sun is swiftly travelling through the space of the heavens, carrying with him all the planets and comets; and in the course of his travels may come to new regions of meteors, as to 'fresh woods and pastures new.'"

Our American astronomer, Professor Young, modestly says: "What sustains the tremendous solar heat, I cannot answer."

THE SUN COMPOSED OF ELEMENTARY SUBSTANCES SIMILAR TO THOSE OF THE EARTH.

The following list of elementary substances existing in the globe of the sun is given by J. N.

Lockyer, so far as completed up to November, 1877, by means of the spectroscope: —

"Sodium, iron, calcium, magnesium, chromium, nickel, barium, zinc, cobalt, hydrogen, manganese, titanium, aluminium, strontium, lead, cadmium, cerium, uranium, potassium, vanadium, palladium, and molybdenum."

He says that "the existence of carbon, silicium, thallium, chlorine, bromine, and iodine, though not distinctly confirmed, is probable;" and adds that, "out of the fifty-nine metals found on the earth, thirty-one are known with more or less certainty in the sun." Professor Proctor says: "The existence of iron in the solar orb suggests the similar use of this metal in arts and manufactories as has been made in the progress of human civilization."

Discoveries of similar elementary substances in our sun and in other stellar suns render it not improbable that all the solar systems are constituted like our own, with similar molecules and similar inhabitants, governed by similar material and mechanical laws, and confirm the existence of analogies between celestial and terrestrial phenomena.

CHAPTER VI.

THE EXCITING CAUSE OF SOLAR LIGHT AND HEAT TRACED TO THE MECHANICAL FORCE OF THE REVOLVING HEAVENLY BODIES.

PRECEDING investigations show that the movement of bodies near and about each other puts in motion the electric ether, which transmits to the brain, through the nerves of sight and feeling, the impulses recognized as light and heat.

As it is impossible to penetrate the remote regions of infinite space, the natural method of studying the operation of the solar system is to reason, by analogy, from terrestrial to celestial mechanics. This method, as we have stated, has been sanctioned by the most eminent astronomers. If the mere movement of one disc near another so develops light as to obtain for a simple instrument the name of "Electrophorus," or *sunshine producer*, and if the rotation of one cylinder opposite to another excites a dazzling light, — we may consider that the swift revolutions of more than one hundred and fifty great globes about the sun, seven hundred fold greater than them all, are similarly employed for the conversion of their mechanical force into the light and heat of sunshine.

In the operation of an inductive electrical machine, the disc which is at rest is independently excited by friction, so that it will react when the other disc is turned opposite to it. In the operation of the solar system, instead of an artificial excitation, as of the disc at rest, the great central orb is excited by a swift rotation on its axis (with a surface velocity at the equator of seventy-four miles per minute), opposite to the several planets, each similarly excited by rotation on its axis.

This axial rotation induces electric currents around the sun, and around each of the planets; which thus become polarized.

With the extraordinary magnitude of the central orb, combined with its extreme velocity of rotation, a correspondingly greater intensity of electric excitation of the solar electro-sphere is to be anticipated. These anticipations are confirmed by the observations of astronomers during total eclipses of the sun, while the dark disc of the moon screens its dazzling brightness, and leaves visible only the extreme ring of light, denoted "a *corona*." Observers have described this corona as exhibiting coruscations, wildly darting off far beyond the extreme edge of the solar disc, flashing thousands of miles in tongues of flame. This description corresponds with the flashings and coruscations occasionally appearing in the aurora borealis above the earth's atmosphere. Between the luminous flashings over the surface of the

sun, at times, are openings that disclose the dark portions of the globe beneath; which constitute "spots on the sun." These openings are constantly varying with a rapidity that only the quick movements of the electric ether will explain. "There are instances in which solar spots of fifty thousand miles diameter are formed in a single day; and others, where they disappear as suddenly. The brightest parts are not stationary, but fluctuate like electric flashes." It is also found that "the appearance of solar spots is attended with extraordinary perturbations of compass needles all over the earth." This fact shows the direct relationship and electro-magnetic connection between the solar excitation and the electric currents continually circulating about the earth, which control the movements of all compass needles.

Modern observers have noticed electrical disturbances, similar to those of the aurora borealis, above the great planets Jupiter and Saturn, in duced by their rotations opposite to their numerous moons. Mr. Bond, of Cambridge, describes them as "self-luminous appearances," disclosing dark openings that reveal the body of the planet, somewhat corresponding with the spots on the sun.

That the apparent diameter of the disc of the sun does not show the true magnitude of the solid globe beneath its exterior luminous photosphere,

is manifest from the calculations of the density of the sun at only one fourth of the density of the earth. Were our earth measured from the exterior of the luminous coruscations of the aurora above the atmosphere, its estimated density would be similarly reduced.

The uniform axial rotations of the planetary bodies, by determining the regular circulation of electric currents about each one of them, convert them all into powerful electro-magnets, with the consequent development of reciprocal action and reaction between them all, denoted "the universal attraction of gravitation."

The swift orbital revolutions of the planets of our system, and also those of countless worlds revolving about other stellar suns, in rushing through the electric ether produce continual vibrations, which impinge against the surfaces of all portions of matter composing the material universe. The vibratory impulses being imparted equally in opposite directions against all the external parts of bodies and molecules, neutralize each other, and consequently molecules exist in an *electrostatic* condition. By diminishing the vibratory impulses against one side of a molecule, it is ready to yield instantaneously to the predominant impulses against the opposite side, with a quick resultant movement resembling an "inherent self-motive power" in lifeless molecules. This explanation confirms the definition of molecules

given by Buscovich, as being "centres of forces;" which they really are while subjected to the vibrations of the electric ether equally on all sides.

The great central orb of the solar system similarly serves as a centre of forces, against which impinge the vibratory impulses of the universal electric ether, excited by the orbital revolutions of the planets. From this central point of reaction the vibrations of the electric ether, continually beating against it, are reflected back in sunshine like surges from a rock in mid-ocean, leaving its surface covered with sparkling foam. Without a point of reaction, there can be no action. Action and reaction are always equal and in opposite directions. The sun serves as a point of reaction, like the lump of lime placed in front of a pale jet of oxy-hydrogen flame, which by its reaction develops the intensity of the vibrations of the flame, and produces the dazzling "calcium light." The similar reflection of the vibrations excited by the orbital planetary force, we call *sunshine.*

The reaction from a fine platinum wire is used to develop the intense action of voltaic batteries and magneto-electric machines. The molecules of a *fine* wire are insufficient to conduct the whole force of the electric current, and its action is thus resolved into light and heat. By making a break in a conducting wire transmitting a powerful voltaic or magneto-electric current, the particles of intervening air and of the all-pervading electric

ether receive the impulses, and become points of reaction in vibrations of brilliant light and intense heat.

These analogies teach us to regard the central orb of the solar system as the point of reaction, representing the action imparted to the universal electric ether by the combined force of all the magnetic planets circling around it.

As similar centres of reaction, all the stellar suns serve to reflect the vibrations imparted to them by the surges of the electric ether, put in motion by the orbital revolutions of planets around each of them. The very fact of the shining of each star in the evening sky is the strongest possible proof of the existence of worlds revolving around it, as the exciting cause.

The suggestions of the popular authors before cited, as to the probable causes of the intense excitation of the solar orb, leave the whole question of the original source of solar splendor unsolved.

Without an internal source of supply, or some sufficiently active exterior cause to maintain the solar light and heat, with such an intense and unceasing emission of both, it might well be supposed that the solar excitation would at some time be exhausted, and the orb become the coldest point in the universe.

The case is very different if we consider the sun to be passive matter, reacting, as before stated,

like a piece of lime used for reflecting the brilliant calcium light, or like the readily conducting charcoal points, which are not even kindled while used for the radiating arcs of electric light, rivalling sunshine. They serve as electrodes, like the solar orb, passively to receive and transmit electric excitation. A concave mirror similarly receives and reflects the light and heat of sunshine, with sufficient intensity to melt the most refractory metals, while it remains cold.

The friction of cylinders of electric machines does not heat them, because the action is speedily diffused by the current through the rows of pointed wires arranged opposite to them. In voltaic batteries, the liquids do not become hot by the chemical action of the acids,—the platinum plates and conducting wires serving to transmit the action in closed electric circuits or currents. Neither do the brilliant coruscations of the aurora borealis heat the air or earth beneath them. On the contrary, the coruscations of the brilliant electric flashes, and also of lightning from condensing sultry vapors in the sky, convert the vibrations of heat into electric currents, that quickly carry it off.

To test the effects produced by the electrostatic condition resulting from an equal action of the electric vibrations surrounding a body on all sides, Professor Faraday made an experiment with an insulated metallic chamber, into which, whilst excited by an electrical machine, he entered. He

says: "While the exterior was sufficiently excited to dart off sparks several inches in length from the outer sides, I could not detect the least evidence of the *existence of any electric action within the chamber*."

Considering the globe of the sun to be in a highly excited electrical state, corresponding with the metallic chamber, or with the earth overarched by the coruscations of the aurora borealis, we may rationally discard the theory of its being covered with billows of flaming gases or molten lava, seething like the crater of a volcano, or that it suffers the terrible pounding of falling meteors and asteroids. The great central orb may have an unvarying temperate clime, exempt from extremes of summer heat or winter cold, with no nights of gloom. It may even be a bright and cheerful dwelling-place, with sunny landscapes; a paradise of perennial verdure and ever-blooming flowers.

If a few small magnets revolved around the axis of a magneto-electric machine suffice to illumine more than a thousand square miles of dark headlands and waters, — reasoning from terrestrial to celestial mechanics, how indescribable must be the magnificence of that lighthouse in the heavens, whose beams are the result of the combined movements of more than one hundred and fifty vast magnetic planets revolving around the central orb of the solar system!

As long as these mighty planets continue to revolve, so long will the sun continue to shine. The question of the *source* of solar light and heat is therefore resolved simply into that of the source of natural motive-power; namely, the axial rotation and orbital revolution of the heavenly bodies.

CHAPTER VII.

ARTIFICIAL EXCITATION OF LIGHT BY MAGNETO-ELECTRIC MACHINES.

MORE than thirty years ago, attempts were made to utilize the excitation of voltaic batteries for illumination. The subsequent plan of exciting electric light by revolving magnets has revived hopes of success. Professor Faraday, the originator of this mode of producing electric excitation, was employed by the British government to construct for a lighthouse on the shores of the British channel a magneto-electric machine, operated by a steam-engine of three-horse power. A like machine, afterward placed in a lighthouse on the opposite French coast, is described as "making three hundred revolutions per minute, and producing a light equal to that of nine hundred Carcel burners." "The lines of the spectrum, and the photographic pictures thereby produced, are equal to those produced by sunshine."

In this machine, "the heat transmitted by the electric current through a platinum wire of No. 18 gauge and eight feet long, instantaneously fused the wire. A round file, four inches long and half an inch diameter, was burnt away in five minutes."

Quite recently, numerous improvements have been made in the construction and operation of magneto-electric machines, for a more general utilization of the electric light.[1]

The principal difficulty in the practical use of the electric light is the regulation of its dazzling brilliancy, which is painful to the eyes, and attended with a contrast of very dark shadows. To obviate this objection, experimenters have attempted to soften the brilliancy by reflection from white ceilings, resembling daylight. Another difficulty occurs in the gradual wasting away of the particles of the carbon points, used at the break in the circuit; which the electric flame must leap across, to transmit the vibrations of light through the electric ether pervading the particles of air. These points require to be moved nearer together by automatic apparatus, to compensate for their gradual wasting away; and when the current is stopped, it is necessary to reinstate the circuit by a new contact of the points, and to make a new separation, for a voltaic and magneto-electric circuit are alike checked by a very small interval of space.

In attempting to avoid these difficulties, ingenious experimenters have devised self-regulating

[1] A machine exhibited at the Fair of the American Institute in New York, is described as "producing a single electric circuit for operating four lamps, each equal to the light of three thousand candles, or two hundred five-feet gas-burners, requiring for its maintenance a force of seven-horse power."

carbon points, and also the use of a circuit of fine wires for developing, by their molecular vibrations, the excitation transmitted through them, in the phenomenon of *incandescence.* But these molecular vibrations disintegrate the wires and render them liquid, or aëriform, and incapable of use. If the intensity of the electric excitation by magneto-electric machines were equal to that excited by rotated inductive machines, this difficulty would have been obviated, as the latter transmit flashes through a foot or two of space. The difference between the extent of motive-power requisite to operate a magneto-electric machine and a Holtz inductive machine, is about inversely as the length of the electric sparks produced by them. A very slight motive-power operates the inductive machine, while several horse-power is requisite to operate magneto-electric machines. A great amount of mechanical force is necessary to put the electric ether in motion at the instant the wires are connected to make the circuit.

This impressive fact affords evidence of the conversion of mechanical action into light and heat, and also of the transmission of motive-power by electric ether with its high velocity, and affords a prospect of utilizing the electric medium by conducting wires, as a substitute for bands and shafts in operating machinery at a distance.

The question of cost and conveniency of exciting electric light, not of its efficiency, must event-

ually determine the extent to which it may be used.

Professor Anthony, of Cornell University, states, as the result of his experiments in burning kerosine oil in lamps, and beneath a boiler for power to produce a magneto-electric light, that the latter mode was nearly double in efficiency with the same quantity of oil. With the cost of machinery and skilled labor to operate magneto-electric machines, and the inconveniences of employing motive-power on a small scale, the problem of the general use of electric light remains to be practically determined.[1]

These illustrations demonstrate that light and heat, constituents of sunshine, are produced by mechanical impulses imparted to revolve magnets about a central axis; analogous to the natural revolutions of the magnetic bodies of the planets about the central axis of the solar system, as a sublime magneto-electric machine in continual operation in the heavens.

[1] In view of the great extent of motive-power requisite to operate magneto-electric machines, with the minute extent of its sparks, and the minute amount of motive-power requisite to operate Holtz' electric machine, with its brilliant sparks leaping one or two feet through the air, it may be a question for experimental determination whether this mode of excitation may prove more efficient for illumination with the same amount of motive-power applied to rotate glass, or ebonite plates.

CHAPTER VIII.

THE SENSORIAL NERVES CONSIDERED AS INSTRUMENTAL TESTS OF PHYSICAL SCIENCE.

ELEMENTARY molecules are classed as *similar*, because they transmit similar reactions and modifications of the axial and orbital forces, through the electric ether pervading the nerves leading to the brain. The planetary force being the immediate source of this mechanical action, all we know of molecules is their power of modifying the action of this force.

The electro-mechanical reaction from molecules being transmitted through five peculiar arrangements of conducting fibres, denoted "Sensorial Nerves," the study of the special functions of these nerves, as instrumental tests of physical science, is of primary importance to a right interpretation of the action they transmit to the brain.

The electric signals transmitted through the sensorial nerves are as unintelligible to a newborn infant, as are the intermittent clickings, or the dots and dashes, to a new apprentice in a telegraph office. To ascertain what the flame of a candle is, an infant attempts to grasp it; and thus practically learns the intensity of its vibrations by

the extreme thrill of the nerves of feeling recognized as pain. The conversion of mechanical action into heat is early learned by the sensation of warmth felt on rubbing the hands forcibly together, long before the knowledge is theoretically acquired. The impression of "seeing stars," produced by a blow on the head, is another exemplification of the conversion of mechanical action into light.

The mechanical action of the orbital planetary force being made manifest by reaction from the sun as sunshine, we must look to this reaction for the immediate source of sensation, and of knowledge of the world around us. It is narrated in classic story, that "the rising sun excited the morning breezes to thrill the chords of the harp of Memnon to melodious vibrations." So the exciting power of the rising sun thrills the nerves of every living animal, as the attuned strings of a harp. The vibratory solar reaction is modified by the lily and the rose, so as to reach the eye in varied *colors;* it is modified by their exhalations, so as to reach the olfactory nerves as *odors;* it is modified by the juices of plants and fruits, so as to reach the nerves of the tongue as *flavors*.

A general inattention to the true functions of the sensorial nerves, as tests of physical science, has so blended ideas of mechanical causes and effects as to be still a most serious obstacle in the way of knowledge. Identical mechanical im-

pulses are called by as many different names as there are different lines of sensorial nerves serving to transmit the action to the brain. This is exemplified in the following table: —

DIFFERENT NAMES GIVEN TO THE SAME ELECTRO-MECHANICAL ACTION TRANSMITTED THROUGH THE FIVE SENSORIAL NERVES.

Mechanical action, transmitted by electric ether through the nerves . .	Of sight,	Of feeling,	Of tasting,	Of smelling,	Of hearing,
Is variously recognized as	Light.	Heat.	Flavor.	Odor.	Sound.
	Darkness.	Cold.	Flavorless.	Odorless.	Silence.
	Colors.	Temperature.	Various Flavors.	Various Odors.	Musical Tones.

From inattention to the functions of the sensorial nerves, an identical electro-mechanical impulse is ascribed to three different causes, — Heat, Light, and Electricity. For ages these have been considered "Imponderable Agents of Nature," employed to produce the phenomena appearing on the surface of the world around.

To avoid errors, the student of physical science requires primary instruction in the use of the tools he is destined to employ. Because two different arrangements of nerves — those of the eye and of the hand — are requisite for holding communication harmlessly and painlessly with heated and ignited bodies, this is no apology for calling the *cause* of these different intensities of excitation by the two different names of "Light" and "Heat;" although it is useful to designate the different *effects* produced thereby by different

names. The gelatinous fibres of the nerves of feeling in the hand would serve only once for contact with an ignited body. They would by that single contact be converted into vapor. To hold communication with ignited bodies without pain or injury, there is provided another arrangement of telegraph nerves from the brain to the retina of the eye; which is studiously protected from liability to injury by highly excited bodies. The ball of the eye is sunk within a socket, covered by an external shutter adapted to close "as quick as a wink." The ends of the optic nerves, denoted the *retina*, are placed behind a watery lens, with an aperture arranged to be automatically closed by too intense excitation of light. The exterior of the eye-ball is also kept constantly cooled by a trickling fountain of tears.

By these ingenious arrangements, the optic nerve holds communication with intensely heated bodies without injury. It may be convenient to give different names to the sensations produced by the transmission of electric action to the brain through different nerves; but this does not warrant us in ascribing the ignition of a fine wire, excited by the discharge of an electrical jar, to three different causes, named Heat, Light, and Electricity. As well might the transmission of electric action through three different telegraph wires to a telegraph office, be ascribed to three different agents of Nature.

CHAPTER IX.

CORRESPONDING VIBRATIONS TRANSMITTED BY THE ATMOSPHERIC AND THE ELECTRIC ETHER.

MECHANICAL impulses imparted to the particles of air are transmitted in currents as winds; and in vibrations, as sounds. Imparted to the electric ether they are similarly transmitted in currents and in vibrations. The interchangeable vibrations and current movements of the electric and atmospheric ethers are illustrated in the operation of the Telephone. Impulses of the voice as words, or musical sounds, excite corresponding synchronous vibrations of the atmospheric and electric ethers, producing similar vibrations of a metallic disc connected with telegraph wires, through which they pass in currents to a second, or terminal, disc. This last in turn transfers them to the adjacent particles of air, which vibrate on the tympanum of the ear. A little bony *malleus*, hung against the tympanum like a knocker on a door, intensifies the excitation of the electric ether pervading the conducting nerve leading to the brain; where, as Galen taught, "the spirit enthroned in a pure luciform vehicle" receives the signals.

When closed circuits are used, the transmission is by means of currents, which will be here-

after noticed. The elastic vibrations of the air and electric ether are thus shown to correspond. To converge the vibrations of the air, as sounds, more forcibly against the tympanum of the ear, ear-trumpets are used.

Concave arched surfaces of domes also reflect the vibrations of sounds.

To concentrate the vibrations of the electric ether, as light, more powerfully on the retina of the eye, the converging lenses of telescopes and concave reflectors are used. The same electro-mechanical action that is transmitted to the eye as light, might serve for a telegraphic communication from the sun, or even from the great star Sirius, if a thermoscope were placed at the aperture of the telescope where the eye is usually adjusted. The light would produce movements of a magnetic needle, similar to those employed in Wheatstone's telegraph for transmitting signals across the ocean.

The electric ether partakes of the passive character of all matter in its incapability to stop itself when put in motion. Light and sound are perpetually transmitted. The continuous progression of light through infinite space is graphically illustrated by an astronomer, who says: "In adjusting my telescope, during the day, toward a remote hillside, I beheld some boys robbing an orchard. If that robbery had been committed on a remote star, and had my telescope been sufficiently per-

fect, I might have seen the act a thousand years after it was committed." It would seem that sunbeams are recording angels.

VARIED RAPIDITY OF VIBRATIONS OF THE ELECTRIC AND ATMOSPHERIC ETHERS PRODUCE PRISMATIC COLORS AND MUSICAL TONES.

The principal difference between the transmission of impulses by the electric and atmospheric ethers is due to the extreme elasticity and lightness of the former, as manifest in the transmission of a flash of lightning with the velocity of light (one hundred and ninety thousand miles per second), while the sound of thunder traverses the air with the velocity of only eleven hundred and fifty feet per second.

When vibrations of the air impinge against the tympanum of the ear less often than twenty-eight pulsations in a second, each one is distinctly heard; but when more rapidly repeated, a fresh impulse is received before the tympanum comes to a state of rest, — thus producing a continuous humming sound, until one hundred and twenty-eight vibrations per second are reached. Then the regular musical tone of the bass note, c, is heard.

By increasing the number of vibrations of the air from one hundred and twenty-eight to one hundred and forty-four per second, the next higher musical tone of the gamut is produced; and so on successively, each higher note up to one hun-

dred and sixty, to one hundred and ninety-two, to two hundred and forty, &c., until twenty-five thousand vibrations per second are reached. Then the tympanum has not time to recoil before another impulse arrives, and the result is a cessation of tympanum vibration, recognized as silence. So the excessively intense vibrations of the electric ether imparted to the retina by gazing at the dazzling sun produce a silence of vibrations, or blindness, corresponding with darkness. "Dark with excess of light."

In like manner, the prismatic or rainbow colors are produced by a different rapidity of vibration of the electric ether; so that the chromatic scale of musical tones of the gamut, and the chromatic scale of colors, depend alike on the different rapidity of the vibrations of the atmospheric and electric ethers.

Instruments have been ingeniously devised for indicating the number of vibrations per second of the electric ether, requisite to produce the chromatic scale of colors.

As sound moves with the velocity of eleven hundred and fifty feet per second, by dividing this distance by the number of aërial vibrations in a second, the length of a vibratory wave is estimated. The velocity of the ether producing the excitation of light being one hundred and ninety thousand miles per second, the length of the waves of colors is similarly estimated; as shown in the following

TABLE OF VIBRATIONS IN CHROMATIC SCALE OF COLORS.

Prismatic Colors.	Number of vibrations in an inch.	Lengths of vibrations in parts of an inch.	Vibrations in a second; English notation.
RED	39,180	0.0000256	477 billions.
ORANGE	41,610	0.0000240	506 „
YELLOW	44,000	0.0000227	535 „
GREEN	47,460	0.0000211	577 „
BLUE	51,110	0.0000196	622 „
INDIGO	54,070	0.0000185	658 „
VIOLET	57,490	0.0000174	699 „

The slowest vibrations of the ether are first recognized as a *red* color, which corresponds with the slowest vibrations of the bass note of the musical gamut; and the quickest vibrations appear as the *violet* hue, which corresponds with the highest musical note audible: for, as previously stated, when the vibrations of the air exceed a certain limit, the tympanum of the ear has not time to recoil before a succeeding impulse arrives, and it remains motionless. So the retina of the eye ceases to vibrate beyond the limit of the violet, and darkness follows. Darkness and silence are, therefore, equivalents of the cessation of vibrations of the retina and tympanum respectively; as cold is, also, of the cessation of vibrations through the fibres of the nerves of feeling.

CHAPTER X.

CONVERTIBILITY OF VIBRATIONS OF HEAT INTO ELECTRIC CURRENTS.

THE vibrations of the electric ether, constituting heat, are readily converted into a current in one determinate direction through the circuit of a conducting wire, so as to turn the needle of a galvanometer, by merely arranging in contact the ends of two bars of metal, one of them a good electrode, and the other a less free

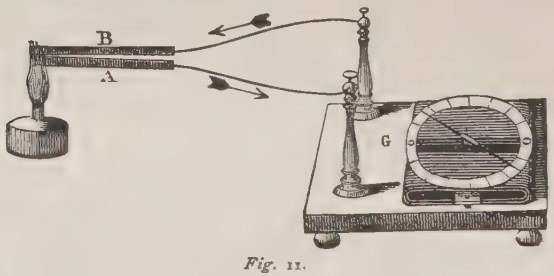

Fig. 11.

electrode, over the flame of a lamp; as represented in Fig. 11. The vibratory movements of the ether become resolved into one uniform direction through the most ready conductor, so as to make a closed circuit; as denoted by the direction of the arrows. The excitation of the current being caused by heat, the descriptive name of Thermo-electricity has been given to this mode of pro-

ducing electric currents. The two kinds of metal conveniently used for this experiment are antimony and bismuth, or German silver and brass.

Were both bars of equal conducting powers, the equal resistance of each would counterbalance the other, and the excitation would take the form of molecular vibrations of the metals, with their gradual heating and expansion.

For experimental use, small thermo-electric batteries are compactly made with little strips of metal, duly insulated from each other by intervening varnished silk; as represented by Fig. 12. The ends of the conducting wires are inserted in the screw cups *x y*,

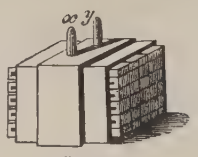

Fig. 12.

to lead the currents in a circuit around a galvanometer needle. This is so sensitively affected by the least excitation of heat applied to the conjoined ends of the combined metallic bars, that the combination is denoted a Thermoscope; which is a far more delicate test of heat than any thermometer; $\frac{1}{1500}$ of 1° of Fahrenheit being sufficient to move the galvanometer needle. The bars of antimony and bismuth are insulated from each other by varnished silk, with their alternate ends soldered together. This arrangement, for very delicate experimental purposes, is used at *a p* with a reflector, as represented by Fig. 13, with screens and tubes adapted to exclude collateral radiations. To prevent currents of air, the

galvanometer is covered with glass, *f*, connected with the apparatus by conducting wires, *h g*. The galvanometer needle is suspended by a single

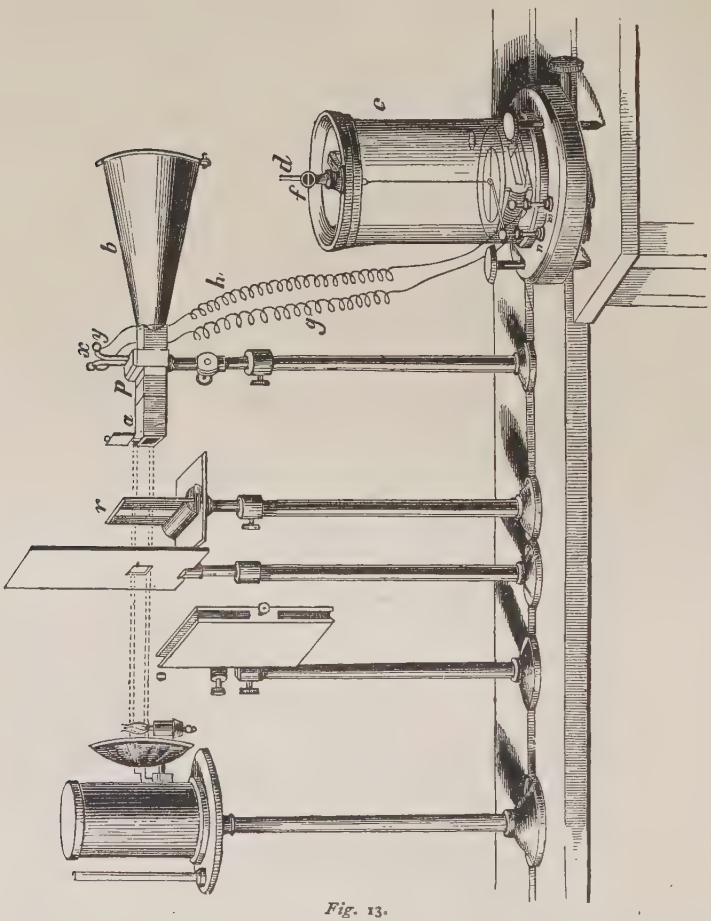

Fig. 13.

flexible fibre of silk. The intensity of the thermo-electric excitation is denoted by the extent of divergency of the needle. The heat of the body

of a person approaching within thirty feet of this instrument, and even of the bodies of insects, of phosphorescent wood, putrifying fish, &c., are detected by the motion of the needle, as stated by Nobili and Melloni.

An ingenious experimenter, Dr. Locke, of Ohio, describes in "Silliman's Journal" a thermoscope with a current changer affixed thereto for reversing the connections, whereby a needle weighing one and one half ounces was made to revolve by the heat of his finger, by timely reversals of the currents.

It may seem surprising that the use of a lump of ice, instead of a lamp flame, will produce movements of the galvanometer needle. A battery is made (Fig. 14) by applying a frigorific mixture on the bars at A, and a plate of heated

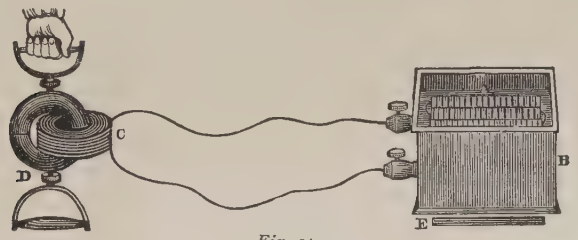

Fig. 14.

iron, E, at their lower ends. On the upper ends of the metallic wires, packed together with insulating varnished silk, and inclosed in a curb, B, is placed pounded ice or snow, with some salt representing the polar seas; and beneath the lower extremities of the wires is

arranged the plate of hot iron, E, representing the torrid region of the earth. With these extremes of temperature, the excitation is intensified sufficiently to produce bright electric flashes, and other electric phenomena, corresponding with those developed by electrical machines. By transmitting this electric excitation through void space in a bell-glass, the flashings of the aurora borealis are represented, as before stated. Between the polar seas composed of salt water and ice, and the torrid zone heated by sunshine, there are north and south currents, above the terrestrial currents circulating from east to west, which appear occasionally as "the northern lights" or aurora, crossing the terrestrial currents, and consequently disturbing magnetic needles on the earth's surface beneath them. Every *local* disturbance of temperature of the earth's surface, by inducing excitation of currents transverse to those regularly circulating from east to west about the earth, disturbs and agitates the compass needle.

The following experiment is of practical interest. An experimenter arranged a sheet of copper and of iron, with one of the ends of each in contact, within the flue from a furnace. The other end of each plate he connected by a wire, extended to an office one hundred and fifty feet distant, making a circuit about a galvanometer needle. He states that he was thus enabled to know the

intensity of heat in the furnace flue, by the movement of the magnetic needle, which performed the functions of a thermometer.

This experiment illustrates, on a minute scale, the frequent movements of compass needles, observable when sudden changes of temperature are produced by sunshine and cold storms in adjacent localities, and more especially while the flashes of the aurora borealis occur. The eruption of red-hot lava from volcanoes, and other causes, are found to produce nearly simultaneous perturbations of compass-needles all over the globe, as verified in national magnetic observatories.

The ready conversion of heat into electric currents, that transmit the excitation to remote distances over the earth's surface, accounts for the sudden disappearance of heat on the condensation of steamy vapors of thunder-clouds, and various phenomena of "latent heat."

Taking for a basis of calculation the mechanical action of seven hundred and seventy-two foot-pounds as the equivalent of the molecular vibration of one pound of water, in raising its temperature one degree from 39° to 40° Fahrenheit, and estimating the temperature of red-hot iron at about 1000°, and assuming the increment of heat in iron to be the same as in water ($772 \times 1000 =$), 772,000 foot-pounds may represent the intensity of molecular vibration of a pound of red-hot iron; and may serve also to indicate the extent of me-

chanical force requisite to render a pound of iron red-hot. The molecular vibrations of the iron excite vibrations of the electric ether pervading the particles of surrounding air, and transmit the impulses to the retina of the eye, producing the sensation of a *red* color; and to the nerves of feeling, producing a sensation of *heat*. In suddenly cooling hot steel by the process of tempering, the surface exhibits the changing colors from a *white* heat to *red*, *orange*, *purple*, *violet*, and *blue;* the latter representing the elastic molecular state of blue watch-springs. These facts indicate that there is a chromatic scale of molecular vibrations developing colors, corresponding with those of the atmospheric and electric ethers developing musical tones.

The remarkable flitting colors on the surface of heated steel are due to the gradual union of molecules of oxygen with the carbonized iron. Thus, metallic oxides serve as pigments, in their peculiar molecular conditions of union with oxygen and carbon.

MOLECULAR VIBRATION ADOPTED AS A TEST OF HEAT.

The vibration of molecules of mercury in the bulb of a thermometer, and their consequent occupancy of more space, denoted Expansion, is adopted as a standard test of heat; precisely as the extent of reciprocal divergency of the pith-

balls of electroscopes is adopted as a standard test of electric excitation. The extent of mechanical action is therefore the standard test of the excitation of both heat and electricity. Various scales of degrees of expansion are adopted in thermometers for measuring the extent of vibration of molecules produced by heat. Reaumur's thermometer is graduated into eighty equal parts of a glass tube, ranging between the freezing and boiling points of water, with a *minus* scale of degrees extended below the freezing point. The thermometer invented by Celsius has 100° between the freezing and boiling points, with a similar *minus* scale. Fahrenheit, to obtain a greater range of degrees, adopted the extremely low temperature produced by a frigorific mixture of snow, or ice, and salt, as a zero point, with a graduation of 32° to the ordinary freezing point of water, and 212° to the boiling point.

Different kinds of substances have each a peculiar extent of molecular vibration, and consequent expansion. Mercury, being the most uniform between the freezing and boiling points, is selected for use in the bulbs of thermometers.

VIBRATION OF THE ELECTRIC ETHER EXCITES VIBRATION IN PARTICLES OF ALL MATTER.

The particles of all kinds of bodies — solid, liquid, and aëriform — are made to vibrate by heat, and transmit action by means of the electric me-

dium pervading the particles of the atmosphere, so as to reach the nerves of sight, feeling, and hearing. This is verified by Trevelyan's experiment with a semicylindrical piece of heated brass, B, resting on a piece of cold lead, L, Fig. 15. The lead being a slow conductor of heat, the vibrations of the particles produce a rocking of the brass, B, like a cradle, and at the same time an audible vibration of the air, like that of the glass plate of a harmonicon. The vibrations produced by combustion of a jet of gas within a glass tube cause a similar musical sound.

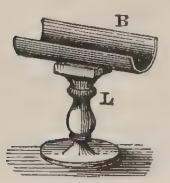

Fig. 15.

It is the rapid and violent vibration of the molecules of hot bodies that causes the stinging sensations they produce, like those by a blow of a rod on the skin, with the result of similar contusions and blisters of the epidermis. Scalding and burning of the skin are wounds produced by the molecular vibration of heated bodies.

If the vibration of sunshine be intensified by lenses upon mercury to 680° Fahrenheit, it boils like water; and the particles are separated so far asunder as to occupy more space than an equal weight of particles of surrounding air, and to ascend buoyantly as mercurial vapor. On the contrary, if the vibration, or heat, be reduced to 39° below zero (Fahrenheit), the terrestrial electromagnetic currents predominate, polarizing and

uniting the molecules of mercury in crystals of frozen solid metal, resembling silver.

Between 39° and 680° the molecules of mercury remain in an equilibrial state, wherein neither the magnetic nor the diamagnetic currents predominate. In this condition of equilibrium, the molecules of mercury have freedom to roll quickly over one another in the liquid state; from whence this metal derives its descriptive name of "quicksilver."

This example of the solid, liquid, and vapory conditions of mercury represents the solid, liquid, and aëriform conditions of all other kinds of elementary substances; including oxygen, hydrogen, and nitrogen, as experimentally verified by Pictet and others.

The contraction and expansion of fluids in thermometers show the alternate predominance of the electro-magnetic currents induced by the axial rotation of the earth, and of the magneto-electric vibrations induced by the orbital revolution.

CHAPTER XI.

POPULAR DOCTRINES OF ELECTRIC AND MOLECULAR VIBRATION, DENOTED HEAT.

THERE are so many theories of heat and light as sources of motive-power, that our limits will permit us to notice but a few of the most recent.

A summary of existing scientific opinions, originating from distinguished philosophers and chemists, appears to be embodied in a treatise on "Heat Considered as a Mode of Motion," by John Tyndall.[1] Other more definite treatises have been written at various times, from which this popular writer has gleaned various views.

He begins the investigation with the following words: —

"What is the agent by means of which we can overpower the force of the winds and rivers? The achievements of heat by the steam-engine have impressed upon thinking minds this important question."

He continues: —

"Let us commence our researches with heart and hope. If we succeed, we shall satisfy, to an extent

[1] D. Appleton & Co., New York, 1867.

before unknown, the love of systematic order and harmony, which is implanted in every mind."

The result of his interesting inquiry is the final conclusion, that "heat is a mode of motion," — a conclusion anticipated by Bacon more than two hundred and fifty years ago; who said, that "all knowledge of heat is limited to ideas of a peculiar mode of motion, produced by some unexplained cause." Others have considered the reciprocal divergency of particles by absorption of heat (denoted expansion), to be somewhat analogous to the swelling of a sponge by the absorption of water.

As to *what* moves, or is put in motion, or is the cause of the motion which develops the phenomenon of heat, Mr. Tyndall gives no solution: he leaves it, as Bacon left it, an "unexplained cause."

To illustrate how heat is produced by motion, Mr. Tyndall and other chemists refer to the motion of a hammer in pounding a piece of lead, or iron on an anvil; whereby the metal is speedily rendered hot.

Mr. Tyndall affirms: —

"The dynamic power of heat is due to what is called chemical affinity, which is a pure attraction of the same mechanical quality as gravity; causing every oxygen atom, in the process of the combustion of a diamond in oxygen gas, to strike against its surface, and to transfer its motion, by collision, into the mode of motion we call heat. . . .

"The ideas of the best-informed philosophers are as yet very unsettled as regards the exact nature of heat. The great starting-point is to regard heat as motion of some kind; leaving its more precise character to be dealt with by other investigators."

The sensation of heat, produced by its action on the nerves of feeling, he explains in the following words: —

"The impression of heat which one receives on entering the hot room of a Turkish bath, is caused by the atomic cannonade which is there maintained against the surface of the body."[1]

He further specifies: —

"We are to figure a gaseous body as one whose particles are flying in straight lines through space; impinging, like little projectiles, upon each other, and striking against the boundaries of the space which they occupy. . . . So likewise in regard to forming steam: the heat is consumed in pulling asunder the liquid particles of water, and in conferring upon them a still greater amount of potential energy. . . . When the heat is withdrawn, the vapor condenses, and the particles again clash together with a dynamic energy equal to that which was employed to separate them. The heat then reappears. . . .

"The disappearance of heat, which enters bodies while changing from solids to liquids, and from liquids to aëriform states, is ascribed to internal work done among the molecules, — which is latent heat; the external work being denoted sensible heat. . . .

"The percussion of the earth against the central orb of the solar system would produce an extent of heat equal to that producible by the combustion of fourteen

[1] Heat considered as a Mode of Motion, lecture iii.

globes of carbon, each equal in magnitude to the globe of the earth."

Mr. Balfour Stewart very graphically describes the clashing of molecules by chemical affinity, in a comparison with a conflict between soldiers on a battle-field; where many are wounded, and some "run away, and live to fight another day:"—

"There is a warfare going on in the clashing together of the molecules, which, although continually maimed, yet always recover themselves; until perhaps some effective blow is struck, which dissevers them from compound substances."

Mr. Tyndall explains the extent of heat developed by the clashing of molecules in the process of combustion of one pound of hydrogen with eight pounds of oxygen, in the formation of water, as follows:—

"We find that the concussion of one pound of hydrogen with eight pounds of oxygen is equal in mechanical value to the raising of forty-seven million pounds one foot high. I think I did not overrate matters when I previously said that the force of gravity, as exerted near the earth, is almost a vanishing quantity, in comparison with the molecular forces developed. Bear in mind, too, the distances which separate the molecules before combination; distances so small, as to be utterly immeasurable. Still, it is in passing over these minute distances that the molecules acquire a velocity sufficient to cause them to clash together with this tremendous energy. . . .

"After this combination of the molecules of one pound of hydrogen with eight pounds of oxygen, forming nine pounds of water in the state of steam of 212°,

the particles of steam next fall together by condensation into liquid water. The mechanical value of this second act is calculated by multiplying the nine pounds of steam by 966° of latent heat = 8,694 pounds of water heated 1° of Fah't ; which, reduced to foot-pounds by multiplying by 772 (Joule's standard), we have 6,711,768 foot-pounds as the mechanical value of the mere act of condensation. . . .

"The next great fall of our nine pounds of water is from the state of a liquid to that of solid ice, the mechanical standard value of which act is equal to nine hundred and ninety-three thousand five hundred and sixty-four foot-pounds. . . .

"Thus our nine pounds of water, in its original formation and progress into ice, falls down three great precipices, which may be estimated by the fall of a ton weight down the first precipice twenty-two thousand three hundred and twenty feet high ; the second, by the fall of a ton down a precipice twenty-nine hundred feet high ; and the third fall, by the descent of a ton down a precipice four hundred and ninety-six feet high. . . .

"The number of foot-pounds of mechanical force developed by the three successive clashings of the one pound of molecules of hydrogen, and eight pounds of molecules of oxygen, is thus estimated by the fall of a ton nearly five miles ; and is equivalent to over fifteen hundred horse-power."

Overwhelmed by such truly astonishing and "tremendous" mechanical results, the professor finally gives utterance to his astonishment in the following graphic words : —

"I have seen the wild stone-avalanches of the Alps, which thunder down the precipices with a vehemence almost sufficient to stun the observer. I have also seen

snow-flakes descending so softly as not to break their fragile spangles. Yet to produce from aëriform gases a quantity of that tender material, which a child might lift, demands an exertion of energy competent to gather up the shattered blocks of the largest stone-avalanches I have ever seen, and project them to twice the height from which they fell." [1]

Favre and Silbermann have applied the British thermal unit (seven hundred and seventy-two foot-pounds), to measure the quantity of heat imparted to bodies to change their component particles from solid to liquid states, and from liquid to aëriform states, in carrying out the dynamic theory of heat as "a mode of motion." They give the following calculation of the extent of action developed by "the clashing of one pound of molecules of hydrogen with eight pounds of molecules of oxygen, in the process of combustion, producing nine pounds of water."

DYNAMIC ACTION OF MOLECULES.

Combustible.	Lbs. of Oxygen.	Lbs. of Atmospheric Air required for combustion.	Total Heat British Units of 772 lbs. ea.	Evaporative Power from 212°.
			Units.	lbs. of Water.
1 lb. Hydrogen Gas	+8 = 9 lbs. Water.	36 lbs.	62.032	64.2
1 lb. of Carbon . . .	{ + 2.67 = 3.67 Carb. Acid Gas. }	12 „	14.500	15.0
1 lb. Coal Gas . . .	+3.43 = 4.43 „	15 43 „	21,344	22 1

Another chemist explains the clashings and encounters of molecules in the following words: —

[1] Heat considered as a Mode of Motion, Lecture V. By John Tyndall, F. R. S.

"When two molecules come within a certain distance of each other, a mutual action takes place between them; which may be compared to the encounter of two billiard-balls."

In a recent paper, Professor J. P. Cooke explains the theory of molecular vibrations in the following words: —

"Conceive what a molecular storm must be raging about us, and how it must beat against our bodies, and every other exposed surface. The molecules of our atmosphere move on an average nearly four times slower than those of hydrogen under the same conditions; but as they weigh about fourteen and a half times more than the hydrogen molecules, they strike with equal energy. Do not think the effect of the blows insignificant, because the molecular projectiles are so small; for they make up by their number for their small size. Consider, for example, that a cubic yard of air contains over two pounds of molecules, which are vibrating with an average velocity of sixteen hundred feet a second, equivalent to that of a cannon-ball of equal weight rushing at the same tremendous rate. If the movements of the molecules were all turned to one direction, instead of opposite vibratory directions, even the massy pyramids could not withstand this destructive violence. In the midst of this molecular tornado, our preservation depends on the beating of the storm in opposite directions; and so precisely counteracting, that we are wholly unconscious of the tumult of molecular forces."

These molecular vibrations are discovered by the microscope continually taking place to such an extent, that Dr. Carpenter cautions microscopists not to mistake them for vital forces. The vibra-

tions of molecules are described as being "an incessant quivering, with so quick a motion as to render it difficult to follow out the course of any one single particle, while changing its direction fifteen or twenty times a second."

Professor Jevons describes these movements as "the leaping of atoms, while freely movable as liquids."

The preceding statements are presented to show the fact of the continual and rapid vibration of the molecules of terrestrial matter, which we have ascribed to the momentum of the planets.

Every molecule, even of solid bodies, being surrounded by the electric ether, has a certain scope and extent of vibration, and continually trembles from the original impress of the Almighty Power, primarily imparted to the vast orbs of the solar system.

Each molecule, while subjected on all sides to equal and oppositely directed vibrations, is held in an *unstable, electrostatic condition.* It is ever ready to yield to the vibrations against one side, when the counterbalancing vibrations are diverted from the opposite side.

When the vibratory action predominates against one side, a resultant movement is so instantaneously produced as to resemble inherent self-motive power in the molecules.

DIFFUSION OF THE MOMENTUM OF THE SOLAR SYSTEM BY ELECTRIC CURRENTS AND VIBRATIONS.

The vibrations diffused through the universal electric ether by the orbital revolutions of the planets, are modified by the currents excited by their axial rotation.

The various movements of matter on the earth's surface are produced by modification, by diffusion, and change of direction, of this grand motive-power. The planets, in rushing through the electric ether, produce vibrations that are continually impinging against the surfaces of all molecules and bodies surrounded and permeated by the ether. These vibrations, when intervening between two molecules or bodies, would force them asunder were they not counterbalanced by vibrations impinging against their outer sides. On bringing together two molecules, or bodies, they partially screen one another from the force of the vibrations around them, — as the inner shores of two adjacent islands in the ocean are screened, leaving their outer sides subject to undiminished impulses from the waves. A change of direction in the undulations of the water may be effected by a current of wind which drives the waves off shore, or, blowing parallel with the shore, neutralizes their action upon it.

That the vibrations of water and atmospheric and electric ethers can be neutralized, admits of

demonstration. Hold vertically two parallel sheets of paper, while blowing a current of air from the mouth between them. The current changes a part of the atmospheric vibrations at right angles with the inner surfaces of the sheets of paper to a corresponding current parallel with their adjacent surfaces, and thus partially neutralizes their action. The vibrations against the outer sides of the sheets of paper, relieved of counteracting force, predominate, and propel the two sheets toward each other; producing a resultant movement by the combined action of the vibrations without, and a current between them.

A similar resultant movement of two bodies takes place, by converting the vibrations of the electric ether between their adjacent sides into currents, as described in Chapter XII.; whereby resultant movements of two parallel conducting wires are produced reciprocally toward each other, at right angles to the direction of the currents through them, — exhibiting the phenomenon of Attraction.

When two surfaces are thoroughly in contact, as of glutinous, or homogeneous bodies, the vibrations and currents between their inner surfaces cease, leaving the vibrations against their outer surfaces to predominate; holding them together, and producing the phenomena of Adhesion and Cohesion.

The orbital revolutions of the planets transmit vibrations on a sublime scale through the electric

ether, which pervades infinite space. The axial rotations produce continuous electric currents about every planet and molecule; and, modified and combined, these produce all the phenomena of molecular movements and of Universal Gravitation.

As before stated, the vibrations of the electric ether, excited by all the stellar suns, are transmitted through the earth's atmosphere sufficiently to act on the retina of the eye as starlight, though too feeble to act on the nerves of feeling as heat, or on the tympanum of the ear as sound.

The Telephone transmits synchronous vibrations through the electric and atmospheric ethers. The vibrations of the air, excited by the human voice, act on the metallic disc of the Phonograph, causing a pointed wire to indent a sheet of tin-foil. The same pointed wire may be made to act as a pawl and rotate a ratchet wheel, which will turn a little balance wheel with surprising rapidity; as stated by Mr. Edison.

A piston, like the disc of a phonograph, is acted upon by the atmospheric vibrations (excited by the planetary force transmitted through the all-pervading ether), with a force not only sufficient to indent tin-foil, but equivalent to a continuous pressure of fifteen pounds on each square inch on both sides of the piston; which counterbalance each other, and produce no movement, until the vibrations, impinging against one side of the piston, are neutralized, or counteracted.

Then the continuous vibrations of the air against the one side of the piston predominate, and, being relieved from the action of an equal force on the other side, produce a resultant movement of the piston. Instead of the complex apparatus of an air-pump for producing a vacuum, a simple plan is employed in the mechanics of Nature, by merely changing the vibrations impinging directly against the surface of a body to another direction parallel with the surface.

Jet-pumps constructed on this peculiar principle are now used instead of air-pumps, to produce a vacuum for raising water by atmospheric pressure. A swift current of air, of steam, or of water, in a jet from the pipe A, will convert the atmospheric vibrations into a rectilinear current through the pipe C; as represented in Fig. 16.

The atmospheric vibrations in the pipe B, immersed in water, are changed from a vertical direction against the surface of the water at the lower end of the pipe B, to a horizontal direction in the pipe C, parallel with the surface of the water. By thus relieving the water in the lower end of the pipe B from ver-

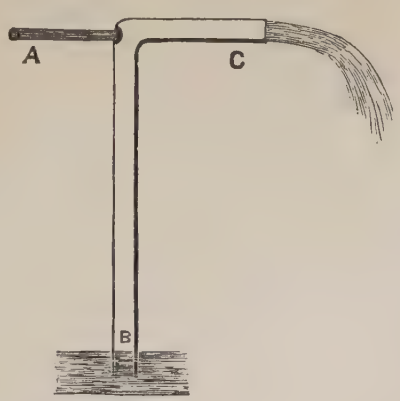

Fig. 16.

tical atmospheric vibrations, while their action on the surface of the surrounding water continues undiminished, the external vibrations predominate, forcing the water to ascend in the perpendicular pipe B, and to flow in a continuous stream from the end of the pipe C.

A similar arrangement, called "Gifford's Injector," is now commonly used for feeding steam-boilers as a convenient substitute for a forcing pump.[1]

A beautiful illustration of the impinging of vibrations against the sides of bodies is seen in placing a light ball or globe in contact with the ascending current of a *jet d'eau*. The ball rises with the current and clings to it; being propelled up as often as it tends to fall. The ascending stream converts the atmospheric vibrations against the side of the ball next the stream into parallel currents; whereby the continuous vibrations against the outer side of the ball predominate, and produce a resultant movement of the ball toward the centre of the stream.

As with terrestrial so with celestial magnetic currents; the stronger will always overpower the

[1] A simple plan of producing an atmospheric vacuum, as a substitute for an air-pump, is also used on railroads for operating brakes to check the speed of locomotives. The blast of a jet of steam over the end of a pipe connected with a cylinder having two movable pistons, arranged as air-tight heads, forms a vacuum in the cylinder, that allows the external vibrations to press simultaneously against both of the movable pistons, producing their resultant movement toward the middle of the exhausted cylinder. Rods attached to each of the two piston-heads then draw in the friction brakes against the rims of the wheels, and check their speed.

weaker, causing the latter to conform in direction about their nearest sides.

According to this law, as the earth turns on its axis from west to east, and the terrestrial currents move from east to west, we may draw the inference that these terrestrial currents are overpowered by the huge sun-magnet and made to revolve in the same direction as the solar currents, conforming in direction about their nearest sides. The solar currents must therefore move in the same direction in which the sun rotates on its axis, and determine the direction of the axial currents and electro-magnetic polarity of the planets, independently of the direction of their several rotations.

By changing the position of a bar of iron from a horizontal to an oblique direction, corresponding to the dip of a dipping needle, the bar is instantaneously rendered an electro-magnet by the terrestrial currents.

This bar-magnet will induce corresponding currents in small pieces of iron, as nails and screws, which are also attracted reciprocally toward each other.

The facility with which electric currents change their direction is shown in the artificial current changer, by which they are reversed several thousand times a minute.

Vibrations *directed obliquely*, as well as those *directed vertically*, against molecules and bodies, produce resultant movements at right angles to their surfaces at the point of impact.

A similar resultant movement of molecules and bodies at right angles to the surface impinged upon, is illustrated by the parallelogram of forces in the annexed diagram. Elastic particles moving obliquely at the angle of incidence, A, impinge upon the surface of B, and rebound at the angle of reflection, C. The resultant movement will be in the direction D B, at right angles to the surface at the point of impact; the angle of incidence being equal to the angle of reflection, and in an opposite direction.

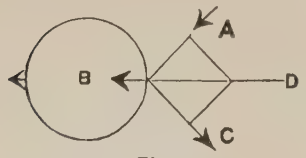

Fig. 17.

CHAPTER XII.

ELECTRIC ATTRACTION AND REPULSION (SO CALLED) ARE RESULTANT MOVEMENTS.

IT is found experimentally that electric currents transmitted through electrodes in *similar* directions, produce reciprocal movements toward each other; and from each other, when transmitted in *opposite* directions.

Fig. 18 represents two parallel conducting wires, A B, supported on the prongs C D E F, and counterpoised by the weights *b b;* so as to swing toward and from each other freely as pendulums. Arrangements of connecting wires are made to transmit currents through them at pleasure, in similar and in opposite directions. The currents moving along the adjacent wires in similar directions, by a process of induction, change the vibrations between

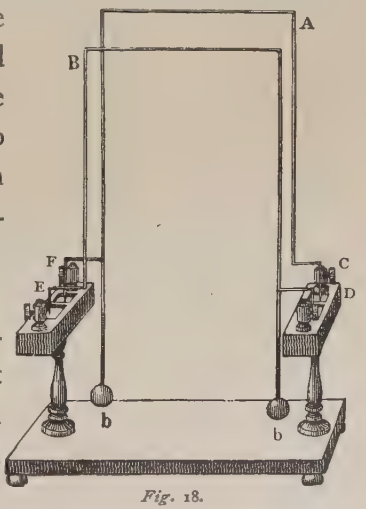

Fig. 18.

them into conforming currents parallel with their surfaces; thereby partially neutralizing the vibrations against the nearest sides of the wires. The vibrations impinging against their outer sides then predominate, and propel the two wires toward each other, — producing the phenomenon of Attraction.

When the currents move in opposite directions along the adjacent sides of electrodes, their interference intensifies the vibrations between them; which then predominate over the vibrations impinging against their outer sides, and propel the two wires from each other, — producing the phenomenon of Repulsion.

Attraction and Repulsion, however diverse the movements may appear, are alike the *resultants* of joint forces, — which act in similar or dissimilar directions, — and not of a single impulse acting in one direction.

That one body can intervene and screen another from the rectilinear transmission of vibrations, is manifest by the obstruction of sound and light incident to such intervention, and by the production of dull sounds and shadows, silence and darkness.

The intervention of the moon screens a portion of the earth from the vibrations of light during an eclipse of the sun.

It is the peculiar function of all matter passively to receive and transfer impulses; as is accom-

plished by the propelled globes of rotating planets; which, like propelled rifle-balls, are sped on their way, transmitting impulses imparted to them, and executing the will of a calculating intelligence.

The vast universe was propelled into space by an all-wise and all-powerful Maker; and that propulsive action, which thrills every world and molecule, will cease only by the exercise of that Maker's will.

The governing principle of the material universe is *Propulsion* rather than *Attraction*.

It now remains to investigate the reciprocal movements of bodies, produced by *transverse* electric currents.

How do the currents circulating from east to west about the earth produce the horizontal movements of compass needles, turning them around on their pivots? By experimental investigation with conducting wires arranged near one

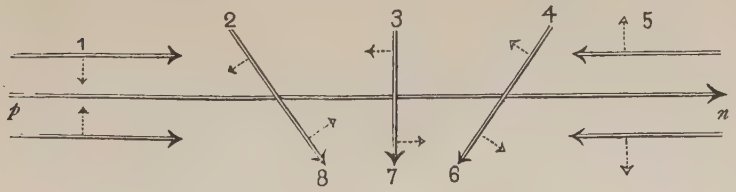

Fig. 19

another, in various relative directions, it has been ascertained that bodies serving as electrodes are propelled in directions rectangular to the lines of the currents, as represented in Fig. 19.

An extended electric current is represented by *p n*. Sections of terminated currents on each side of *p n*, and crossing at various angles, are denoted by the arrows numbered from 1 to 8. The several resultant movements are designated by the short arrows.

Much ingenuity is requisite to render bodies freely movable while connected with electric apparatus.[1]

To exhibit the reciprocal action and reaction between bodies serving as electrodes, and transmitting currents in various relative directions, an eminent experimenter contrived a light wire frame, suspended on pivots P and N (Fig. 20), resting in cups containing mercury to insure conduction. The lower side of the frame E W, when arranged parallel with the conducting wire *p n*, transmitting currents in the same direction beneath it, is in its most stable position of reciprocal attraction. To whatever position the wire *p n* may be turned horizontally, the under side of the frame will follow it, and retain the same relative direction.

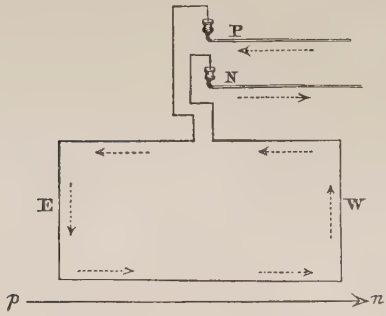

Fig. 20.

[1] For an account of various original experiments in Electro-dynamics, reference may be had to the *Annales de Chimie et de Physique*, vol. xv., p. 93.

The terrestrial electric currents from east to west about the earth are represented by the current *p n*, and will cause the wire frame, while transmitting a current, to turn in a conformable direction east and west, and to manifest all the characteristic properties of a compass needle, with a north and south polarity.

Considering the extended conducting wire *p n*, in Fig. 19, to represent the direction of the terrestrial currents from east to west, and the diagonally directed currents 2 3 4, 6 7 8, the directions of currents approaching to and receding from the horizontal terrestrial current, the short lateral arrows would designate the resultant movements, — all at right angles to the linear direction of the short wires, according to principles previously explained. In Fig. 20, the vertical descent of the current at E, toward *p n*, develops the resultant movement denoted by the short lateral arrow No. 3 in Fig. 19, which tends to swing the end of the frame E horizontally around; while the ascent of the current, at W, represents the relative direction corresponding with No. 7 in Fig. 19. The resultant movement indicated by the short, dotted, lateral arrows, Nos. 3–7, turn it to correspond in direction with the current *p n*.

To illustrate the identity of the reciprocal action between electric currents circulating around conducting wires, and the natural currents circulating about loadstones, and all other magnets,

De la Rive contrived to render conducting wires freely movable, setting them afloat on pieces of cork, as represented in Fig. 21. To excite currents through the floating wires A B *a*, he affixed to their lower ends zinc plates opposite to copper plates, and immersed them in acid in a basin. They then became electro-magnets. The directions of the currents are denoted by the arrow heads.

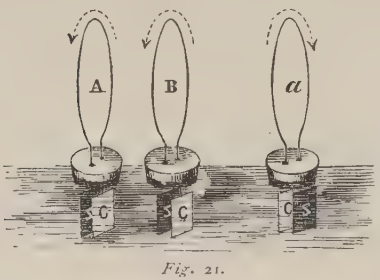

Fig. 21.

The rings, A B, about which the currents move in *similar* directions, sail toward each other; while the ring *a*, which transmits the current in an *opposite* direction to that about B, is repelled. It gradually turns around, so that the sides about which the currents move in similar directions face each other; then they are propelled together.

These pieces of conducting wire, while serving to transmit electric currents, manifest all the characteristic properties of magnets similarly set afloat on pieces of cork by the ancient philosophers, as previously described.

Although a compass needle points its poles, or ends, north and south, apparently crosswise of the terrestrial currents from east to west, yet it is to be remembered that the electro-magnetic currents circulate about the axis of a magnet, and not

longitudinally; so that the terrestrial currents from east to west, and the currents about the under side of every compass needle, are finally brought to move in similar directions.

The phenomenon of terrestrial magnetism is admirably illustrated by Professor Barlow's invention of winding numerous circuits of insulated

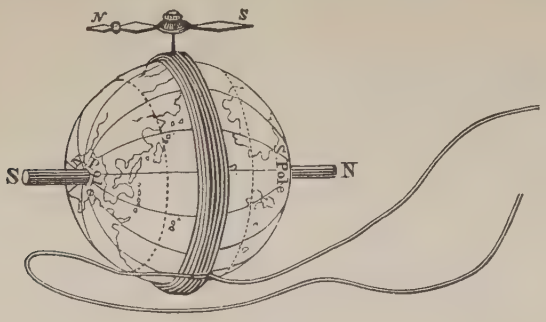

Fig. 22.

conducting wire about a little globe, with a compass needle mounted on top of it, as shown in Fig. 22. By employing intense battery currents from a voltaic apparatus, to overpower the terrestrial currents, all the phenomena of terrestrial magnetism are exhibited.

Until the connection of the conducting wire is made with the voltaic battery, the compass needle placed on top of the artificial globe takes its usual north and south direction, pointing to the poles of the earth; but as soon as the overpowering battery current is transmitted through the conducting wire wound in numerous spiral coils about the little globe, the compass needle turns and points

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steadily to the N and S poles of the artificial globe; and faithfully continues to point to them in whatever direction it may be turned.

To increase the intensity of the electric currents, Ampère multiplied the number of circuits, by winding the conducting wire in a spiral; Fig. 23. This simple apparatus develops all the characteristic functions of a magnetic needle mounted on a pivot. One particular end always turns toward the north pole of the earth, and when disturbed returns to that direction. This coil serves to represent the transverse position of the magnetic needle mounted on the little globe; w represents the cross-section or end of a conducting wire transmitting a current in a direction from east to west, corresponding with the direction of the terrestrial currents. The battery current through w, being more immediately powerful than the terrestrial electric current, in whatever direction the conducting wire w may be turned in relation to the cardinal points, the floating coil will turn and become arranged with its underside currents moving in the same direction as the current in w; and will always remain stationary in a position *crosswise* to the current through w.

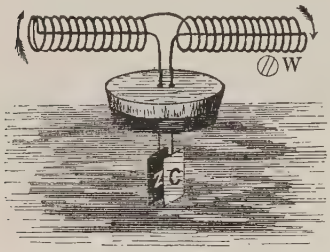

Fig. 23.

If the wire w be held above the spiral coil, where the circling current is in an opposite direc-

tion, the coil is turned around so as to bring the current on the upper side in the same direction, and the ends or poles of the spiral coil are reversed.

The mathematical precision with which the movements of electrodes conform to the rule of "reciprocal attraction between similarly directed currents," is seen in the peculiar movements of dipping needles, in arranging their positions in relation to the circulation of the terrestrial electric currents, as exhibited in Fig. 24.

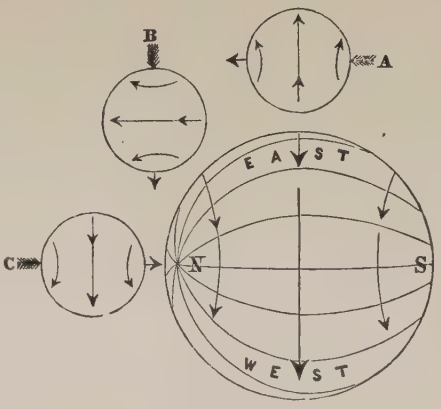

Fig 24.

The direction of the currents from east to west about the earth is represented by the arrows, and also the direction of the currents about the compass needles A B C; to which spherical outlines are added, to show the directions of the electro-magnetic currents about each of them when transferred from the earth's equator, at A, toward the pole, at B and at C. The inclination of the compass needle, at B, shows the actual movement of a dipping needle; and the currents about B, and about the earth in that latitude, as will be manifest on inspection, are brought to move in similar directions by the "dip" of the needle. The needle, at C,

is turned entirely around. The several relative positions of the dipping needle are designated in Fig. 25 by the arrows, arranged on different parts of the earth's surface.

Fig. 25.

That the phenomenon of magnetism is excited by terrestrial electric currents, is verified by the following experiments. If a bar of iron be held in a horizontal east and west position, in the line of movement of the terrestrial currents, as represented at B A in Fig. 26, and a magnetic needle be brought near either end of the bar, an equal reciprocal attraction takes place between them. On lifting the end A to a sloping position, as represented by C D, in a line directed toward the north pole of the earth, the terrestrial currents will induce the circulation of currents about the bar of iron, C D, and convert it into an electro-magnet; with the lower end, C, having the same polarity

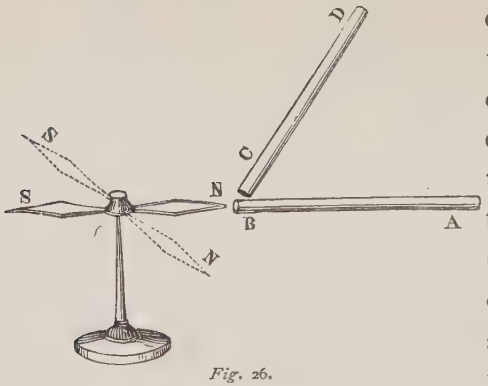

Fig. 26.

as the end of the needle N. Consequently, as the N poles of magnets reciprocally repel each other, the needle is swung around to the position denoted by the dotted needle N S.

In proportion as the end D is lowered to its previous horizontal position A B, in an east and west direction, the magnetic needle swings back, and is attracted again by either end of the bar, indifferently.

This experiment shows not only the action of the electric currents circulating about the earth, but also the sensitiveness of all bodies and molecules of matter to terrestrial electro-magnetic excitation, even by slight changes of relative position in regard to one another, while serving as electrodes. An iron fire-poker, if it happens to remain in the inclined position of a dipping needle, becomes magnetically excited by the terrestrial currents. The large vertical steel-drills used in machine-shops are rendered so powerfully magnetic, that iron chips cling to them after the drill has been used.

CHAPTER XIII.

THE CONTINUOUS CIRCULATION OF ELECTRIC CURRENTS ABOUT MAGNETS AND MOLECULES SUSTAINS THEIR POLARIZATION.

IT may seem incredible that electric currents, whereby molecular and magnetic forces are sustained, can circulate continually about molecules and magnets; but this fact is verified experimentally, and the direction of the circulation may be reversed several thousand times in a minute, with a corresponding reversal of their poles. By placing a common steel sewing-needle within a spiral coil of wire, as in Fig. 27, the slightest transmission of electric action through the coil puts in motion a corresponding circulation of currents about the steel needle, and renders it permanently magnetic. That particular end of the needle, about which the circuit of the current is in the direction shown at s, being similar to that of the hands of a watch about a dial-plate, is found to manifest the peculiar properties of the south pole of a magnet. Where the current comes out at

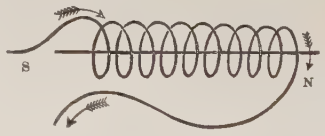

Fig. 27.

the other end of the spiral coil, about which the same current appears to circulate in an opposite direction to the movements of the hands of a watch, the properties of the north pole are excited. But these apparent directions depend on the position of the observer facing one, or the other, end of the spiral coil. It is a remarkable fact, that the presence of about one per cent of molecules of carbon in iron (constituting *steel*), imparts to it the property of retaining the continuous circulation of electric currents, and renders the compound substance of steel *permanently magnetic*. The wonderful facility with which electric currents are excited about a steel needle, has rendered this simple contrivance a very sensitive test of electric excitation. By connecting the ends of the conducting wire with the metallic roof of a large building in Washington, Dr. Page found that a flash of lightning, twenty miles distant, rendered the needle permanently magnetic. Knives and steel implements are often rendered magnets in houses struck by lightning; and even the direction of the currents can be ascertained by examining which end of the steel has the properties of a south pole: see Fig. 26.

If a piece of iron is substituted for a steel needle, it is electro-magnetic only while the current circulates around the coil. The conversion of pieces of iron into powerful electro-magnets is effected by placing them within spiral coils of insulated

conducting-wires, as in Fig. 28. At the instant of stopping and of renewing the battery circuit around the piece of iron inserted in the coil, an

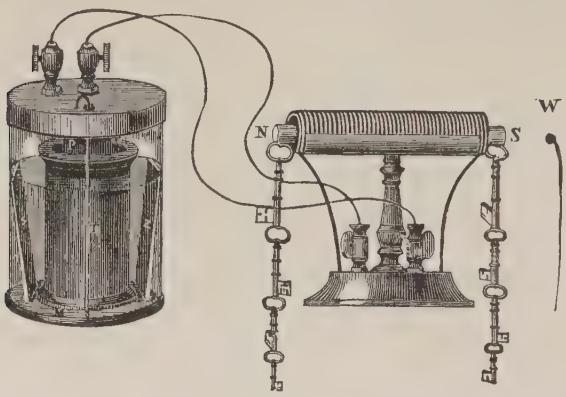

Fig. 28.

electric spark is seen to pass between the iron and adjacent knob, w, showing the disturbance of the electric ether pervading the particles of iron, and thus developing the peculiar electric excitation, denoted "magneto-electricity."

These reciprocal movements of bodies toward each other, and their union while transmitting currents in similar directions, result from the modification of the vibratory impulses against the adjacent and opposite sides of approximated bodies; as previously explained. For this special reason, the movements developed by electric currents, it is to be remembered, are not in the direction of the currents passing over electrodes, but at right angles to them; as shown in Fig. 19, where the actual movements are pointed out by

the lateral arrows on the sides of the conducting-wires, 2 3 4.

These lateral movements imparted to conducting wires by the vibrations impinging against their sides, produce rotations of electrodes when supported on an axis; as in Fig. 29, where a conducting wire is shown at No. 3, as connected with a pivot C, and free to turn around circularly to the several positions indicated by the dotted lines 1 2 4, up to 8, with another conducting-wire, A B, beneath; which may be considered as representing the horizontal terrestrial current from east to west. The small lateral arrows show the resultant rectangular movement of the wire 3, in each of its eight positions relative to A B; thus the wire C D 3 will be kept revolving about the pivot C.

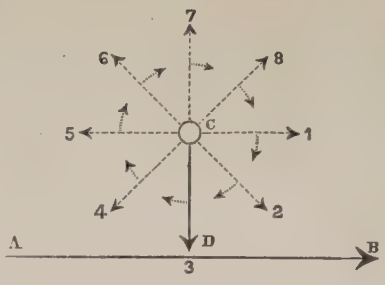

Fig. 29.

To verify the theory that the divergence of electric currents from a central point at right angles to another current (Fig. 29), will produce a revolving motion of the electrode, or conducting body, Faraday placed a watch-crystal filled with mercury within a brass cup and in contact with its rim, which was amalgamated and connected with the screw-cups; this brass cup was environed by conducting-wires, and an electric circuit ar-

ranged to descend vertically to the centre of the mercury. On transmitting a voltaic current in this circuit of screw-cups and wire to the centre of the glass, a whirl of the mercury is caused by the diverging currents from the centre, with a centrifugal force that caused its subsidence beneath the point of the wire, purposely placed a little below the surface of the mercury. The currents circulated first about the coil surrounding the mercury, ascended, and then descended to the centre of the mercury, radiating thence as from the centre c; Fig. 29. The alternate breaking of the connection of the circuit by the centrifugal subsidence of the mercury at the centre of the whirl, and the restoration of the level consequent on the stoppage of the current, cause a repetition of this operation intermittently, as often as the current is restored.

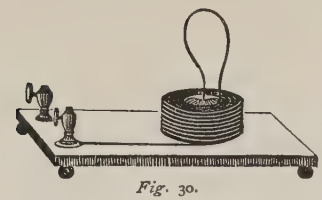

Fig. 30.

By reversing the direction of the current, the direction of the whirl is reversed.

The transmission of vertical electric currents to and fro, between the clouds and the horizontal currents from east to west about the earth, excites a revolving motion of the air similar to that of the mercury, and produces whirlwinds or tornadoes; which are always attended with electric discharges. The breeze, or aura, issuing from the point of a wire on the excited conductor of an electric

machine, shows that the air is put in motion by electric currents.

The uplifting of water by a passing tornado is called a "water-spout." This effect is illustrated by holding the finger over a vessel of water placed on the excited conductor of an electric machine. The water will rise in spray to meet the finger.

The writer had once an opportunity of witnessing, in fearful proximity, the phenomena accompanying the passage of a tornado. An account of it was given in a letter to Dr. Robert Hare, and was by him published in the "Transactions" of the American Philosophical Society, in 1838. This tornado passed over the south part of the city of Providence, and across Narragansett Bay. The central whirl proceeded from west to east through a calm atmosphere, overturning trees and buildings in its path of about one hundred yards in width. Roofs were uplifted, and the fragments were scattered through the air like missiles. To escape them the writer fled to an open field, while the whirling materials moved on with terrific force and an appalling roar of crashing sounds.

In passing over the water the inverted cone of dark mist swerved about like a huge trunk of an elephant, while the surface of the water beneath it was upheaved tumultuously. The adjacent waters foamed like a boiling caldron. At times the dark misty cone of spray was rendered brilliant with gleams of lightning, followed by a momentary lull.

This spectacle inspired awe, commingled with admiration of the sublime display of Omnipotent Power, as graphically described by the Psalmist: "He bowed the heavens and came down. Darkness was under His feet, and He moved on the wings of the wind. He made darkness His secret place, and the pavilion around about Him was dark waters and thick clouds of the sky."

The intense electric excitation transmitted through the vortex of a tornado at Wallingford, Connecticut, is described in a recent account as follows: "In some mysterious manner, the hay from a barn, taken up into the air, was set on fire, and came down all blazing upon the ground."

In the experiment made with the whirling mercury, the direction of the whirl depends on the ascending or descending direction of the electric current; and probably the same law governs the direction of a whirling tornado.

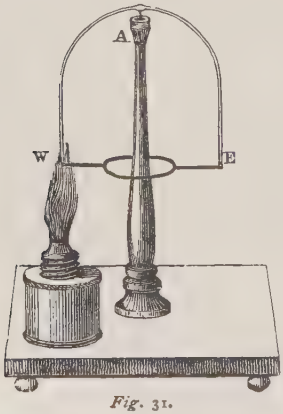

Fig. 31.

Further to illustrate the rotation of a freely movable conducting wire, or other electrode, produced by a current vertical to the horizontal terrestrial currents, the slight excitation of a thermo-electric current may be used; as in Fig. 31, which represents an arched wire frame, W A E, supported on a pivot at A,

and capable of readily turning around it. A circuit is formed by a cross-piece, W E, made of some less freely conducting metal than the arching piece of wire, for the purpose of determining the direction of the circulating thermo-electric current excited by the heat of the flame applied at the joint W. Were equally conducting metals used, the vibratory excitation of heat would be extended by *molecular vibration* of the wire (denoted "conduction of heat"), instead of circulating electric currents. The excitation from the flame of the lamp first ascends the readily conducting side of the arched frame, and descends on the other side, completing the circuit through the less readily conducting metal. The ascending current from W is *vertical*, and at right angles to the horizontal terrestrial currents; and produces a movement of the frame at right angles to the plane of the frame (as indicated by the direction of the small arrow on the conducting-wire No. 7, Fig. 29). The vertical descending current on the other side of the frame corresponds with that of the conducting-wire No. 3; and produces a movement in an opposite lateral direction, as denoted by the small arrow on C D. Both combine to turn the frame horizontally on its pivot. When the side E comes over the flame, the heat reverses the current; and these alternate reversals keep the frame continually turning. A similar revolving motion of a little frame is described by Professor

Crookes, as produced by the action of the light and heat of a lamp, as well as by that of sunshine.

"Four discs, made of light pith, of the size of a sixpence, balanced on the ends of two straws, are adjusted to revolve horizontally on a pivot. The sides of the pith-discs are inclined downwards. They have one side blackened by plumbago, or lamp-black, and the other side white." The Professor says: "When this apparatus is placed under a bell-glass in a vacuum, it will revolve by the action of sunlight or of a lamp." There appears to be an analogy between the revolutions of this frame and those produced by the lamp in the experiment described. The difference of colors of the discs, black and white, corresponds with the difference of conducting powers of the metals employed in the thermo-electric apparatus; and their sides sloping downward correspond with the vertical sides of the wire frame. Then, again, the transmission of the vibrations of the all-pervading electric ether is more obvious beneath an exhausted bell-glass, than in the open air; as illustrated by Fig. 1, page 23.[1]

To determine the different action of terrestrial currents on the vibrations of the electric ether

[1] In a treatise on "Light as a Motive Power," p. 55, by R. H. Armit, R. N., the following explanation is given: "Light has been demonstrated to be both a repulsive and attractive force. The resultant of these forces, as regards the earth, would therefore be, *first*, to hold the earth grasped within the rays of light, as within a pair of tongs. And, *secondly*, these tongs being carried round by the sun in his rotary motion, an orbital motion is given to the earth, and to all celestial bodies receiving solar light."

impinging against the vertical sides of compass-needles, and producing rotation, the writer caused a steel needle to be made, eight inches long, with a width of three-fourths of an inch, and thickness of one thirty-second of an inch, balanced on the point of a sewing-needle, to be mounted either flatwise or edgewise, at pleasure, as represented in Fig. 32. It was anticipated that, in extending the area of the vertical currents on the sides of the needle, a more powerful electro-mechanical action might be developed, producing greater oscillations of the needle. To test this supposition, the magnet was placed *flatwise*, with the N pole pointing south, and then left free to yield to the action of the terrestrial currents: the number of oscillations was repeatedly counted, and found to be twenty-one in 2.75 minutes, before the magnet came to a state of rest. With the *edgewise* mounting, it made twenty-seven oscillations, continuing 3.31 minutes; being twenty-nine *per cent.* more in *number*, and continuing twenty *per cent.* longer in *time*, notwithstanding the greater resistance of the air from the broad side of the magnet.

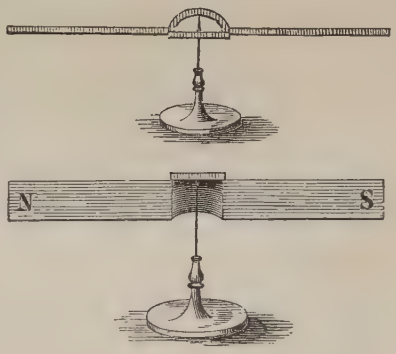

Fig. 32.

EFFECT OF CHANGING THE DIRECTION OF ELECTRIC CURRENTS.

By artificially changing the directions of electric currents transmitted through the approximated sides of bodies serving as electrodes, their reciprocal movements toward, or from each other, are producible at pleasure. This is effected by the use of a "Current-changer," as in Fig. 33. Two elastic steel springs, w w, are severally connected with the two poles of a battery circuit, for transmitting the current first to one half of a semi-cylindrical clasp s, and then to the other half successively, by the turning of the spindle A, shown by a cross-section. The two clasps, s s, are insulated by varnished silk from the spindle, and are severally connected with the two ends of a conducting-wire by which the direction of the battery circuit is to be reversed. This device is used as an automatic current-changer; and, by its timely reversals from an attractive to a repellent electric force, a freely movable coil of conducting wire is made to revolve several thousand turns in a minute.

Fig. 33.

The instantaneous change of direction of circulating electric currents about bodies and molecules, and consequent instantaneous changes from reciprocal attraction to reciprocal repulsion, is shown by the blow of a hammer on a bar of iron, as indicated in Fig. 34.

On gradually lifting the iron bar, s, to the *sloping* position of the dip of a dipping-needle, the circulating currents about the iron bar, induced by the terrestrial currents, are suddenly intensified by the percussion of the hammer, and turn the compass needle rapidly to the position indicated by the dotted lines. The end of the needle, which was previously attracted toward the piece of iron, is suddenly repelled forcibly.

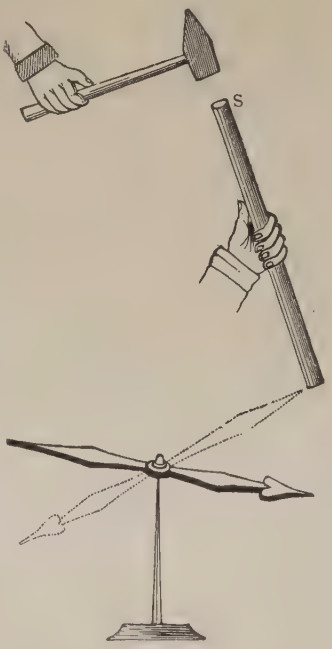

Fig. 34.

This phenomenon shows an analogy to the sudden reaction developed between the particles of percussion powder, commonly used for firing gunpowder. The presence of molecules of nitrogen, combined with molecules of mercury, silver, potash, glycerine, cotton, &c., reduces the compound to an unstable condition of circulating molecular currents, corresponding with those about the iron in the experiment described. The blow of the hammer of a percussion lock suddenly determines the reversal of the molecular currents, with the result of a violent repulsion between them, and explosive

reaction of the combined particles of carbon and hydrogen, in the unstable organic substances of gun-cotton, nitro-glycerine, gun-powder, &c. A gleam of sunshine disturbs the unstable electro-static condition of the nitrate of silver in combination with molecules of carbon and hydrogen, in the organic compound substance of paper, collodion, linen, cotton, and even of the hair and skin; and changes their molecular groupings and capability of reflecting light. The molecules of oxygen and hydrogen in all organic formations are rendered freely movable by the excitation of light, when impregnated with the nitrate of silver, commonly denoted "lunar caustic." The molecules of hydrogen and oxygen become united and produce water, leaving the molecules of carbon revealed as a negative black, on the surface of the organic body. The greater or less extent of carbonization of the surface of white paper, with the different resulting power of reflecting light, develops the lights and shades of photographic pictures, which excite the admiration of mankind as magical productions of sunbeams.

Photographic pictures are really the results of the chemical decomposition of organic substances, corresponding to the decomposition of the human skin and flesh by nitrate of silver, leaving the black charcoal, and liquefying the hydrogen and oxygen into water.

A similar result of the chemical decomposition

of organic substances is produced without the intervention of molecules of nitrogen, by intensifying the solar action by a lens on a sheet of white paper; which is speedily turned brown and black by driving off the molecules of hydrogen and oxygen, and leaving the charcoal.

A remarkably unstable electro-static condition of molecules of hydrogen and of chlorine exists when mingled together; which a gleam of sunshine disturbs, producing their instantaneous union with explosive force.

RECIPROCAL ACTION BETWEEN ELECTRIC CURRENTS AND MAGNETIC CURRENTS.

That there are electric currents continually circling about the axis of a magnet, as about the axis of the earth, is proved by its producing the same reaction as if a spiral conducting-wire were wound around it, transmitting a continuous current from a voltaic battery. The currents circulate in the same uniform direction about the axis of a magnet; but they appear to move in opposite directions, when a bar-magnet is bended to the form of a horse-shoe, as represented in Fig. 35. It may be noticed that the currents about the S pole, when facing the observer, move in the same direction that the hand of a watch moves about the dial-plate, and those about the N pole

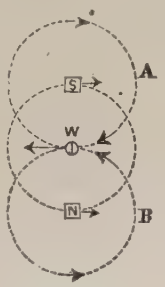

Fig. 35.

in a reverse direction. These apparently opposite directions are the results of bending around the ends. In accordance with the preceding illustrations, the two opposite poles develop a reciprocal attraction; for the currents move in *similar* directions about their nearest sides. About the N poles, or the S poles, of two bar-magnets, when similarly brought near one another, the currents move in opposite directions, with a consequent reciprocal repulsion between them. If two magnetic needles be fastened together with their opposite poles adjacent, as shown in Fig. 36, their reciprocal action and reaction neutralize one another, and the terrestrial currents do not turn this compound needle on its pivot; hence it is denoted a STATIC NEEDLE.

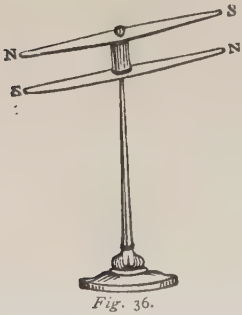

Fig. 36.

In Fig. 35, W, representing the section of a conducting wire between the two vertical poles, N S, is propelled by the two combined magnetic currents in the direction denoted by the arrow, if the electric current ascends through it, and in the opposite direction if it descends. So delicate is the combined action of the magnetic currents circling between the two poles of a horse-shoe magnet, that a flexible strip of gold-leaf is used, as represented between the two poles N S, Fig. 37, for a sensitive test of slight electric currents.

While an electric current is transmitted through the flexible strip of gold-leaf, it is propelled forward or backward, according to the direction of the current up or down. This instrument is one of the most available tests of the slightest transmission of an electric current. A glass tube, T, protects it from agitation by currents of air.

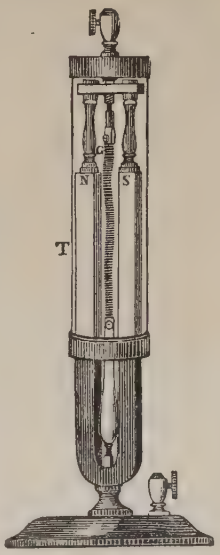

Fig. 37.

The forcible action developed between magnetic and electric currents is most strikingly manifested by the apparatus of a wheel revolving between the two vertical poles of a horse-shoe magnet; as in Fig. 38. By arranging connecting wires in the base-board, the electric current is made to descend from the axis of the wheel into conducting mercury in the trough, to complete the circuit. A swift rotation of the wheel is thus produced, by the action and reaction developed by the co-operation of magnetic and electric currents. The electro-mechanical action is intensified, producing very swift-revolving

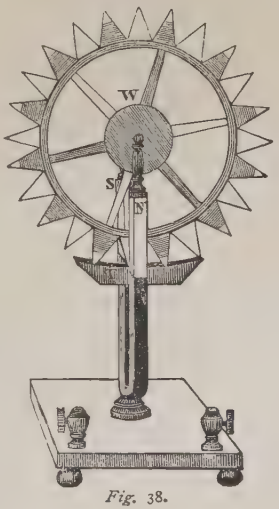

Fig. 38.

movements, by using numerous circuits of conducting-wire in an oblong coil between the two poles of a horse-shoe magnet, as represented in Fig. 39, with the addition of the usual *current-changer*, composed of two elastic springs connected with the oblong coil. This current-changer reverses the direction of the circuit at every half-revolution, and thereby sustains a continuous propulsion to augment the electro-motive power. Mr. Davis says: "This instrument revolves with the wonderful velocity of more than six thousand rotations per minute, and produces a loud humming sound, audible at a considerable distance."

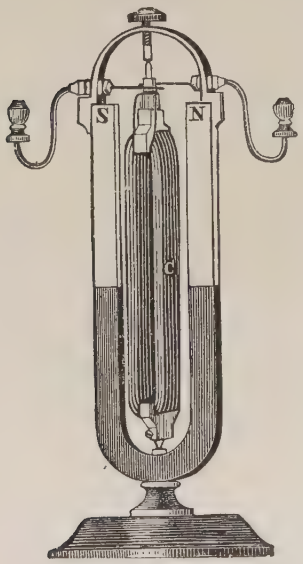

Fig. 39.

Ampère, De la Rive, Wollaston, and other investigators in electro-dynamics, suggested various theoretical relationships of electric and magnetic currents for producing resultant movements, which appear to have been verified with mathematical precision. Faraday, with his persevering sagacity, succeeded, in the year 1821, in exhibiting a conducting-wire revolving

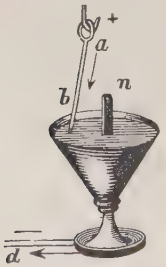

Fig. 40.

about the pole of a magnet in conformity with the tangential forces of the circulating currents, as shown in Fig. 40; which represents a conducting-wire suspended on a loop, transmitting a current to the mercury in a glass, in which a magnet is inserted, with a connection of its lower end with a conducting-wire, *d*, to complete the circuit. The suspended wire revolves about the upper end of the magnet. If the wire be extended the whole length of the magnet, the diamagnetic currents neutralize this action.

He afterward succeeded in producing the reciprocal revolutions of a magnet, M, and conducting-wire W, about one another, as represented in Fig. 41. Mercury was used in the glass for a conductor in connection with the screw cup C.

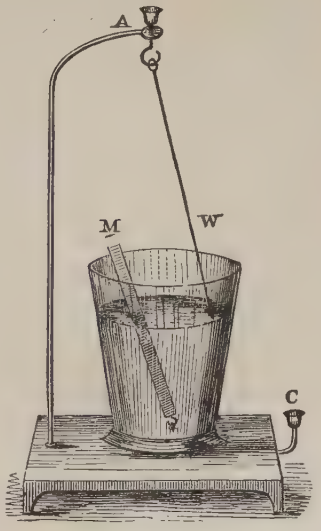

Fig. 41.

Innumerable other combinations of currents and magnets have been invented to illustrate the transmission of electro-mechanical action. Although the principal magnetic power is manifested by the poles, or ends, of magnets, yet a very important action is developed by the currents circulating about the middle or equatorial parts, as previously illustrated

by the artificial globe with a magnetic needle mounted upon it (Fig. 22). This action of lateral electric currents, transversely to the axial polar magnetic forces, is denoted *Diamagnetism.*

CHAPTER XIV.

DIAMAGNETISM.

WHILE only a few kinds of elementary substances — such as iron, nickel, and various crystals — manifest polarized magnetic force, all kinds of substances, including organized compounds, such as wood, coal, &c., manifest diamagnetism when they are held between the poles of a powerful electro-magnet; as exhibited in Fig. 42.

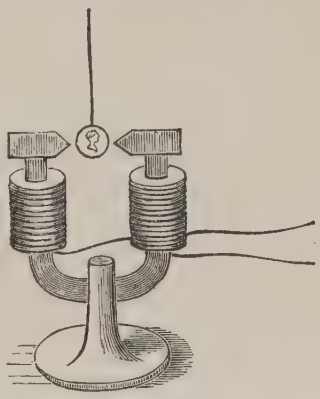

Fig. 42.

The attraction acting on the sides of bodies is commonly exhibited, by suspending them by a flexible thread between the poles of electro-magnets. If a silver or copper coin be thus suspended, it is turned about with the flat sides *diamagnetically* fronting the two opposite poles; while a bar of iron, nickel, bismuth, and various crystals are arranged in a longitudinal position between the two poles.

To show the force of the diamagnetic attraction, experimenters commonly twist the string tightly, to produce a swiftly-revolving motion, whereby the suspended body is caused to rotate rapidly, and is then instantaneously stopped, when it is brought into a position intermediate between the two poles, with the flat sides facing each pole. In accordance with the law of attraction between similarly-directed currents, this phenomenon appears to be due to the inductive excitation of currents about the sides of the coins, corresponding with those excited about the poles of the electro-magnet.

To test the result of whirling bodies by force between the poles of electro-magnets after being thus arrested, an intelligent experimenter fixed the rotated body on a spindle turned by a driving-band from a pulley. He discovered that it became electrically excited, like the pieces of iron rotated between the poles of horse-shoe magnets, in magneto-electric machines; which excite the vibratory movements of the electric ether, recognized as electric light and heat.

Another experimenter placed some fusible metal (composed of lead, tin, and bismuth, which melts at 212° of Fahr.) within a brass tube, and subjected it to rotation between the poles of an electro-magnet. Without friction, or contact, the rotated brass case and its contents speedily became so much excited by this rotation opposite to the

magnetic poles, as to melt the compound metal, which the experimenter poured out on the table of a laboratory.

This experiment is somewhat analogous to the rotation of the earth opposite to the two polarized electro-magnetic bodies of the sun and moon; whereby the *internal heat* of the earth may be similarly excited to fuse crystallized rocks into melted lava, at times poured out from the tubes of volcanic craters on adjacent table-lands, as the fusible metal on the table of a lecture-room.

This experiment indicates that the interior molecules of bodies are excited by their rotation, as well as the exterior molecules on the surface; and that while the orbital revolutions of the planets induce the solar reaction, warming the surface of the earth, its axial rotation warms the interior, — as manifested by the eruptions of volcanoes. The intensity of the excitation of the interior of the earth is found to be regularly increased about 1° Fahr. for each sixty feet of depth; so that by very deep boring for an Artesian well, an abundant discharge of hot water of the temperature of 170° has been obtained, in a German city, for public baths. The Geysers amid the frozen regions of Iceland, and in the valleys of Northwestern America, send forth continually columns of hot water to great heights.

These facts corroborate the general law of diffusion of electro-mechanical action by the axial and

orbital revolutions of the planets, reaching even the very centre of the earth.

The circulation of currents about the exterior of the globe of the earth has been considered by an eminent philosopher as producing the polarization of the interior molecules, as represented in Fig. 43; neutralizing the interior currents in opposite directions about their nearest sides, by clasping them all in one exterior closed circuit, as indicated by the directions of the arrows. With such unstable electro-static counterbalancings of oppositely-circulating molecular currents, it may be readily imagined that a sudden violent explosive separation of molecules of carbon in gunpowder and percussion powder may ensue, on breaking the exterior closed circuit with the blow of a hammer.

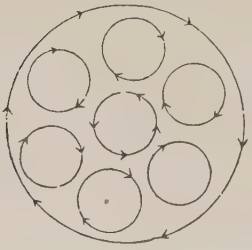

Fig. 43.

CHAPTER XV.

CIRCULATION OF ELECTRIC CURRENTS IN CLOSED CIRCUITS.

INFINITE rectilinear progression in finite space being impracticable, there is a necessity for the recurrence of portions of the electric ether in circles to the same place.

A periodical return of the heavenly bodies to the same place is also the great law of Astronomy; and even the atmospheric ether moves in circles, denoted cyclones. A similar recurrence of the swiftly-moving electric ether to the same place, in circuits about the earth and about magnets, is a law of electro-dynamics.

A remarkable circulation of electric currents is manifest in the arrangement of conducting molecules, or bodies, to form circuits by *rings*; as when the two ends of a horse-shoe magnet are connected by an intervening armature A, as represented in Fig. 44.

Fig. 44.

In a closed circuit, the polarity disappears; for there are no longer any ends, or poles, to the magnet. The external electro-magnetic attraction nearly disappears from the two conjoined halves

of an electro-magnetic iron ring, represented in Fig. 45; while in the closed circuit they are so very powerfully held conjoined, that weights of several thousands of pounds are sustained thereby. The electro-magnetic excitation instantaneously disappears from a bar of iron when the battery circuit is stopped; but in the closed circuit formed by the conjoined semi-circles it continues for a brief time. The union of molecules formed into a ring serves to sustain a compound circulation of electro-magnetic currents, as through the string of a circlet of beads, while simultaneously the electro-magnetic currents circulate about the axis of each individual bead. The combined action of these electro-magnetic currents polarizes electro-magnetic bodies. The action of the diamagnetic current around each molecule is exhibited in the spontaneous formation of rings of vapor floating in the air, resulting from puffs of smoke, of steam, and especially from the explosive combination of phosphuretted hydrogen; as represented in Fig. 46.

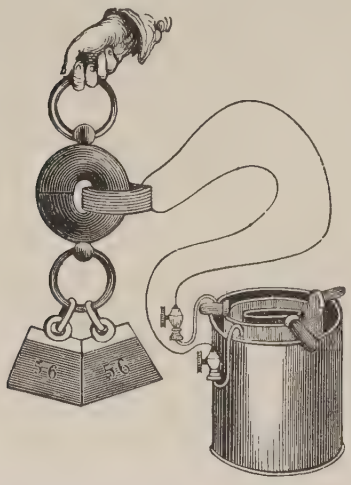

Fig. 45.

This self-inflaming gas issues from the beak of a retort immersed in water, as shown in the figure,

and takes fire explosively on coming in contact with the air; producing a white ring of smoke.

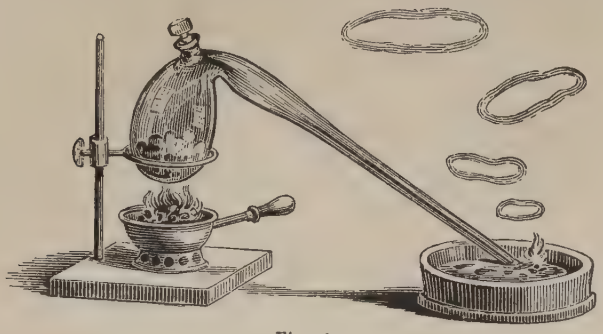

Fig. 46.

The rings successively ascend and buoyantly float in the air, gracefully waving in unbroken circular forms. A rod may be passed through them without breaking the continuity of these closed circuits.[1]

The formation of these rings, and of soap-bubbles similarly floating in the air, and even of the great planetary globes, is doubtless governed by the same electro-dynamic principles of closed circuits, in which the axial magnetic and lateral diamagnetic actions are combined to produce resultant effects of molecular unions.

[1] Helmholtz supposes this vortex-whirl would continue indefinitely in a frictionless medium; which he assumes to be the condition of the space about the planet Saturn, the formation of whose wonderful vapory rings might be similarly produced and sustained. The writer first saw the formation of these vapory rings on the simultaneous discharge of cannon (a *feu de joie*) at the time of celebrating the restoration of peace between England and America, in 1815. Two of these vapory rings, while floating in the air, became interlocked like links of a chain, and were hailed by cheers from the assembled multitude, as an auspicious omen of union.

The polarity of a body may be determined by the molecular polarizations; which neutralize each other when alternately arranged, or co-operate when combined; as in the two parts of Fig. 47.

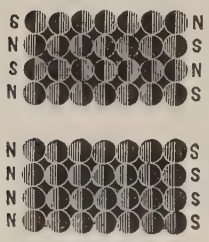

Fig. 47.

The polar action and the diamagnetic action induced by electric excitation between molecules, sustains the continuous union of the particles, laterally and longitudinally, about spherical rain-drops, and in the tenuous film of bubbles, while their contact facilitates the circulation of electric currents in closed circuits around the spheres; as represented in Fig. 43, p. 126.

While the external closed circuits develop electric attraction between the adjacent sides of two bubbles, A B, by moving in similar directions, the opposite directions of the interior closed circuits may produce reciprocal repulsion, and bulge out the sides of bubbles to spheres.

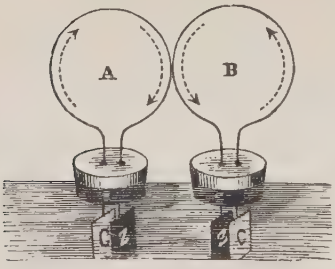

Fig. 48.

The similar circulation of electric currents in closed circuits is not limited to the reciprocal action and reaction between molecules on a minute scale, in terrestrial mechanics; but is extended on

a sublime scale to develop the electro-mechanical action and reaction between the earth and moon, and other heavenly bodies. The circulation of electric currents in closed circuits may be applied to explain the

SIMULTANEOUS RISE OF TIDES ON OPPOSITE SIDES OF THE EARTH.

Previous illustrations show that the globe of the earth is a powerful electro-magnet, excited by the paramount electro-magnetic power of the sun, and with its polarity determined through the solar action. As stronger magnets determine the direction of electric currents circulating about feebler ones, the earth unquestionably determines the direction of the currents circulating about its satellite, the moon, to move in a similar direction about the side nearest to the earth, as represented by the arrows in Fig. 49. In accordance with the principle of action and reaction between electrodes, transmitting currents in similar and in opposite directions, reciprocal attraction ensues between the portion of molecules constituting the nearest sides of the moon and the earth; and reciprocal repulsion between the portion of molecules constituting the side of the moon nearest to the earth and those constituting

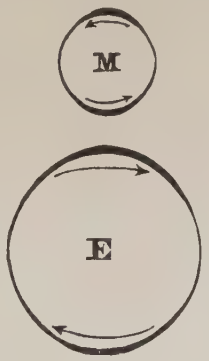

Fig. 49.

the side of the earth most remote from the moon. As electro-mechanical impulses act on individual molecules to produce movements of masses (the *quantity* of molecules in bodies being determined by their gravitating descent toward the centre of the earth), the ocean waters, covering the greater part of the planet, freely yield to the action of the electric currents where they circulate in similar directions about the moon and earth, and flow toward the moon on the side of the earth nearest thereto; while at the same time the waters on the opposite side of the earth yield to the action of the oppositely-directed currents above described, and flow away from the moon. In accordance with general electro-dynamic principles, therefore, there ensues a simultaneous rise of tides on both sides of the earth.

The present popular doctrine of tides gives the following explanation of these phenomena: —

> "The simultaneous rise of ocean-waters on opposite sides of the earth is caused by lunar attraction, which draws away the solid part of the earth from the fluid ocean-waters on the farthest side of the globe, and simultaneously draws away the waters from the solid part of the earth on the nearest side."

But no reason appears to be given for this discrimination between the gravitating action on solid and liquid particles, which is equally efficient in producing the motion of a falling rain-drop and of a falling stone. The similar action of the

earth's currents on the moon renders it permanently oval, or egg-shaped, as discovered by improved telescopes; because that globe has not a rapid axial rotation like the earth, to vary the attractive force.

Although the average height of the rise of the tides is only three or four feet, yet in some localities they rise thirty or forty feet. This extraordinary elevation is due to the momentum of tidal currents, whereby vast masses of ocean-waters are put in motion, impinging against shelving shores and narrow bays, and force up the water, as by currents in hydraulic rams, to considerable heights.

A little additional rise of the tides is produced by the centrifugal tendency of the ocean-waters to recede from the centre of the earth, by its monthly orbital revolution about the common centre of the moon and earth, while they swing around each other.[1]

THE RELATIVE EQUATORIAL POSITIONS OF THE MOON AND EARTH SUSTAINED BY THE DIAMAGNETIC CIRCULATION OF ELECTRIC CURRENTS.

The northern and southern declinations of the moon, denoted its librations, affect magnetic needles, as stated by Professor Bache. This action,

[1] The similar centrifugal tendency induced by the daily rotation of the earth bulges out the equatorial region to thirty miles greater diameter than the axial measure; making a rise of nearly twelve feet to the mile in proceeding from the pole to the equator. The Mississippi River, in flowing from north to south, recedes from the centre of the earth eight or nine feet to the mile, and flows by the *centrifugal* tendency of its waters.

in addition to the tidal action, demonstrates the electro-magnetic connection between the earth and moon.

The extent of the northern and southern librations of the moon, alternately toward the north and the south poles of the earth, is probably governed by the equatorial or diamagnetic currents, which restrain the moon from vibrating more than about 29° each side of the equator. In Fig. 50, M represents a magnet, and C a helix coil, set afloat like the ring of De la Rive, with the appended zinc and copper plates immersed in acids. On bringing the magnet toward the ring-coil, it is found to pass over the magnet, as the eye of a needle is passed over a thread, and continues to move over it until the ring arrives at the middle part of the magnet. There it stops, and remains permanently at rest. The earth, being a magnetic body, represents M, and the currents incident to the circling of the moon in its monthly orbit around the earth, may represent the coil of conducting-wire, C. The reciprocal action and reaction between the diamagnetic

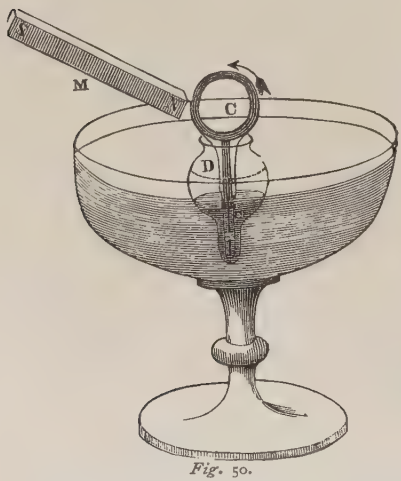

Fig. 50.

currents may hold the moon to its equatorial position in relation to the earth, and prevent its libration beyond the poles while circling around it.

This diamagnetic action may hold also all the revolving planets electro-mechanically in their true axial and orbital positions relatively to the plane of the ecliptic.

The diamagnetic, or equatorial, currents present more extensive surfaces for action than the polar ends of magnets, and have more effective force. The currents circulating around a bar magnet, and those circulating around a spiral coil of conducting-wire wound in the form of a helix, present toward each other the greatest possible extent of surface when the bar is inserted within the tube of the coil; as represented in Fig. 51.

Fig. 51.

The bar of iron, even with a heavy weight appended thereto, is powerfully drawn upward into the interior of the helix, and is upheld there without contact with the coil; thus exhibiting the most perfect possible *elasticity*, by its freely vibrating movements, — as if actually dancing on the air. However often the bar with its heavy weight may be pulled down, it will ascend again, with a perfectly free and elastic recoil and very considerable force.

Some analogy seems to exist between the ascent of the bar within the tube of the helix coil and the ascent of sap in the tubular pores of trees; and also of fluids in lamp-wicks, porous sponges, sugar, &c., — in the manner denoted "capillary attraction."

The ascent of sap against the action of gravitation to the height of three hundred feet in the California cedars, may be thus explained. The force of the absorbent capillary action of sap even in a humble pumpkin, or squash, has been experimentally proved, at the State Agricultural College, Amherst, Mass., to be sufficiently powerful to upheave a weight of several thousand pounds, during its growth.

The phenomenon of the elasticity of steel springs and of woody fibres admits of explanation on this principle of diamagnetic molecular action; which allows of the partial sliding of the particles on one another with a retraction, like the drawing back of the iron bar with the appended weight.

The considerable range of action of the diamagnetic currents, as compared with the polar magnetic action, has been resorted to by ingenious experimenters for utilizing electro-motive power. To test the efficiency of this plan, the Congress of the United States was induced to appropriate twenty thousand dollars for an experimental machine devised by Dr. Page, thirty years ago. To produce a direct rotary motion, he used, instead of

a straight bar, a semi-circular bar of iron, adapted to pass through two semi-circular helix coils.

This machine, operated by a voltaic battery, developed considerable effective power in moving a locomotive engine on a railroad in Washington; but failed to produce mechanical action as cheaply as by the combustion of coal.

CHAPTER XVI.

MECHANICAL ACTION CONSIDERED AS A TEST OF ELECTRIC EXCITATION. — POPULAR THEORIES OF ELECTRICITY.

AS of elementary molecules, so it may be said of the electric ether: all we know of it is its power of transmitting action. For this special reason, light and freely movable bodies — such as feathers, straws, pith-balls, and flexible gold-leaf — are resorted to for receiving and developing mechanical impulses transmitted by the electric ether. For convenient use two balls are commonly employed, made of the pith of elder, and suspended by flexible threads attached to an insulating glass-handle, as represented in Fig. 52. This simple apparatus is called an "Electroscope," from two Greek words signifying "Electricity — I behold;" the movements of these balls being considered equivalent to an exhibition of the transference of impulses by the *electric* ether.

On bringing the pith-balls near a piece of amber,

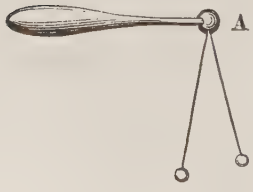

Fig. 52.

A sealing-wax, or other *resinous* substance, after putting in motion the electric ether pervading it by friction, the balls are seen to move directly

toward the resinous substance, A; as represented in Fig. 53. On impinging against the excited body A, the elastic balls rebound, and, having received excitation by contact, are repelled therefrom, and also reciprocally from each other; as represented in Fig. 54.

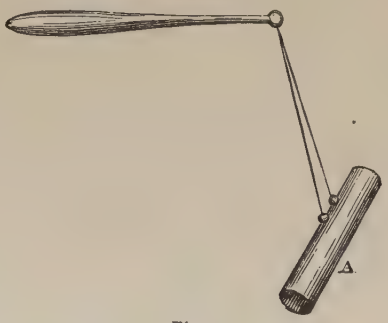

Fig. 53.

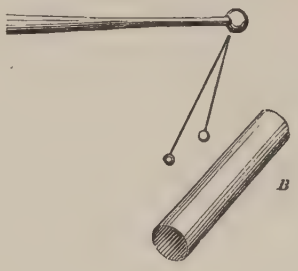

Fig. 54.

If the balls, while thus excited and diverging from a piece of rubbed amber, sealing-wax, or other resinous substance, are brought near a piece of glass, or other *vitreous* substance similarly excited by friction, they are moved directly toward it, and develop the phenomenon called *attraction.*

To explain this remarkable movement of the excited balls *from* an excited piece of amber, or other resinous substance, and their subsequent movement *toward* a piece of rubbed glass, or other vitreous substance, Dufay originated a theory of "the existence of two different kinds of electricity, in the two different kinds of resinous and of vitreous substances; each having self-repellent powers, and reciprocally attractive powers for the

other." The descriptive names of "*vitreous*" and "*resinous*" electricities were accordingly given to them.

But, after further experiments, it was found that if a tube of glass be ground to a rough surface at one end, while the other end is left smooth, and a rubber be passed over the whole length of it, the *vitreous* electricity is manifest only on the smooth part, and the *resinous* appears on the rough part. This showed that a difference of surface, not of material, determines the difference of the electricity. Another experiment of friction of a piece of silk, with one end dyed *black* and the other left *white*, showed that a difference of color similarly determines the kind of electricity excited. In this way, a difference of colors is ascertained in the dark by a difference of mechanical reaction, in clinging together.

These facts discredited the theory of Dufay. Professor Faraday instituted a course of experiments for ascertaining if the supposed two kinds of electricity could be separated; but the task proved as vain as an attempt to separate mechanical action and reaction, which are always "equal and in opposite directions," — precisely like the phenomena of the two kinds of electrical action and reaction, denoted resinous and vitreous.

Franklin and Priestley attempted to simplify the two-fluid theory, by introducing the present popular single-fluid theory, after Gilbert, Newton, and

others had prepared the way. The single-fluid theory is described in Priestley's "History of Electricity" as follows: —

"When the equilibrium of the electric fluid, dispersed through the pores of all bodies, is not disturbed, and when there is in any body neither more nor less than its natural share, it does not discover itself to our senses by any effect. The action of the rubber upon a body disturbs this equilibrium by producing a deficiency of the fluid in one place, and a redundancy in another place; and a mutual attraction of the particles of the fluid is excited to restore the equilibrium. If two bodies be both overcharged, the electric atmospheres repel each other, and both bodies recede from one another to where the fluid is less dense; the electric atmosphere carrying the bodies along with it."

But, unfortunately for this theory, bodies supposed to be devoid of the electric ether, or in a *negative* state, are found to repel one another precisely like those containing an excess, or in a *positive* state. This fact discredits the single-fluid theory.

If the electric ether be a material medium, it must be subjected like all other matter to the same mechanical law of "equal action and reaction in opposite directions." The ether occupying the surface of the rubber, when put in motion transfers the impulse it receives to the similar electric ether occupying the rubbed body; and, being an elastic fluid, recoils by impact, and verifies the general mechanical law of the development of two

equal and oppositely directed movements: as when a cannon-ball is put in motion in one direction, an equal motion, or momentum, is imparted to the cannon in an opposite direction. This simple explanation resolves the mystery of the opposite movements of bodies toward and from one another into effects produced by oppositely directed impulses of mechanical force. This is the obvious way in which every other kind of matter is put in motion. By roughening one end of a glass tube, leaving the other end smooth, the same rubber passed over both surfaces receives different reactions, and the electric ether is put in motion in opposite directions on the surfaces of the glass and rubber.

The terms *positive* and *negative* are also applied to denote the two opposite delivering and receiving ends of electric circuits, or poles of voltaic batteries; which are marked as + and —. The present popular theory of electricity being based on the reciprocal movements of bodies toward and from one another, denoted *attraction* and *repulsion*, it remains to show how these movements are mechanically produced, instead of ascribing them to self-motive and self-directive powers inherent in the electric ether, or in other matter.

In accordance with the reciprocal movements of portions of matter toward and from each other, produced by transmitting currents through

them in *similar* and in *opposite* directions, the following suggestions will tend to explain the peculiar movements of the pith-balls of electroscopes: —

Considering the balls of electroscopes, like all other portions of matter, to be pervaded and surrounded by the universal electric medium in continual vibratory motion, and impinging on their exterior surface equally in every direction, and as being thus held in an *electro-static* condition, — their movements toward and from electrically excited bodies are produced by disturbing this equilibrium of the impulses on one side of the balls, whereby the impulses acting on the opposite side predominate, and propel the balls in the resultant direction of the impinging impulses. All mechanical modes of exciting electricity by friction, or by machines of various kinds, are so many expedients resorted to for disturbing the electrostatic condition of molecules, or bodies of matter, and developing resultant movements of them, — as has been previously described.

The impulse from the hand, imparted to move a rubber over a piece of glass, or sealing-wax, puts in motion the electric ether in circulating currents about them, which induce the circulation of

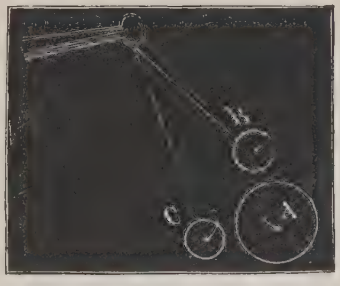

Fig. 55.

currents in similar directions about the nearest sides of the balls of electroscopes brought near these excited substances, as represented by B C, in Fig. 55; precisely as an excited magnet induces currents in similar directions about the nearest sides of pieces of iron, and develops reciprocal attraction between them. On coming gently in contact with the excited body A, an extended closed circuit is instantaneously made about them all, as delineated by the arrows in Fig. 56, and

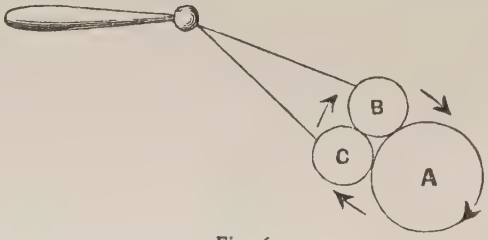

Fig. 56.

conjoins them as one electrode. In this state they will remain united, if the balls do not elastically rebound from contact with A, and leave an intervening space between them, — as occurs when the brass balls rebound from the vibrating sides of the bells of an electrical chime.

At the instant of the rebound the single closed circuit is broken, and is resolved into three distinct closed circuits, whose currents move in *opposite* directions about the adjacent sides of each of the three balls, B C A, as indicated by the arrows in Fig. 57; with a consequent repulsion between all

three of them. If the balls B C, excited by contact with a piece of rubbed amber, A, or sealing-wax, Fig. 57, and while repelled therefrom after contact, be brought near a piece of rubbed glass, they are attracted thereby, because the vitreous currents circulate in opposite directions to those about the amber.

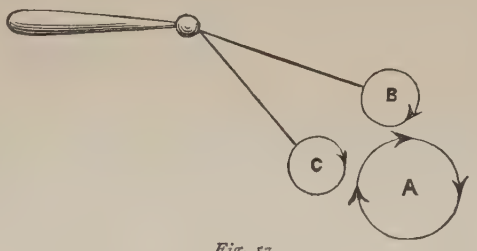

Fig. 57.

The reverse direction of the current about the *glass* (which takes the place of A) coincides with the currents about B and C, with the result of reciprocal attraction between the three.

In tracing out the movements of the balls of electroscopes toward and from each other, as tests of electric excitation, it is to be remembered that the original mechanical causes of their movements are the axial and orbital revolutions of the planets, which combine to produce the various resultant motions of electrodes, — as has been previously illustrated, — and the revolving movements of various mechanisms by the reciprocal actions between different directed currents.[1]

[1] As a further experimental illustration of the combined axial and orbital revolutions of the solar system, the rotation of the disc of a Gyroscope affords an instructive example.

VARIED VELOCITIES IN THE TRANSMISSION OF MECHANICAL ACTION.

Vibration of light transmitted through the electric ether in infinite space is found to be about 190,000 miles per second, being nearly 1,000,000,000 feet per second.

The velocity of vibrations of sounds	in air	. .	1,150	feet	per second.
" " "	in water	.	4,160	"	"
" " "	in wood	.	12,000	"	"
" " "	iron wire	.	15,000	"	"

The velocity of transmission of currents in closed circuits, through short wires of a large size, is nearly the same as that of light. The velocity is greatly diminished in passing through ordinary telegraph wires. The diminution is nearly in the ratio of the squares of the increased distances, and inversely as the size of the conductor. With a fine wire the current is not only interrupted, but molecular vibrations are produced so intense as to disintegrate the wire itself.

It appears, by experiments made by Mr. Walker of the United States Coast Survey, that the velocity of the transmission of electric currents between a telegraph station in Cambridge, Mass., and Philadelphia, was about 18,700 miles per second. Others have calculated a higher velocity. "A communication by telegraph between Bombay and London has been made and answered in thirty-three seconds." "A perceptible portion of a second is occupied in transmitting a telegraphic signal across the Atlantic."

TRANSMISSION OF MOTIVE POWER TO A DISTANCE THROUGH CONDUCTING WIRES FOR OPERATING MACHINERY.

Some interesting experiments were made about thirty years ago for transmitting power from motors to machines through telegraph wires, as a substitute for driving-bands, ropes, and lines of shafting.

A joint-stock company in the city of Providence attempted to utilize the electric ether as a medium for distributing motive-power. A steam-engine was employed to turn a great magneto-electric machine for putting in motion the electric ether, and thereby utilizing it effectively at remote distances. It was supposed that the power of distant water-falls might be thus rendered available for workshops in cities; as the clicking armatures are practically worked in distant telegraph offices.

The company succeeded so well in utilizing this mode of transmitting power from the motor to machines in a workshop, that they were led to believe they had obtained more power than was imparted by the steam-engine to turn the magneto-electric machine; and that consequently they had made "a gain of power," and had secured "Perpetual Motion." But the pockets of the shareholders, instead of being filled, were drained by the machine, to which was given the burlesque name of "Hifalutin."

The labors of this company, however, were not

entirely lost; for they constructed a powerful magneto-electric machine, for ringing the alarm bells for the Fire Department in the city of Boston. This machine was operated by the water-power of the Cochituate Aqueduct. The electro-motive power was transmitted through telegraph wires, detaching weights, which, in descending, rang the bells for a fire-alarm. In this way originated the admirable system of Telegraphic Fire-Alarms.

TENUITY AND VELOCITY OF THE ELECTRIC ETHER.

Momentum is the combined force of *velocity* and *mass*. If therefore, as in the electric ether, there is great tenuity, there must be a compensating increase of velocity to produce a like result. A swiftly projected cannon-ball is the equivalent of a ponderous mass with a slow motion. Light particles of sand driven swiftly against flint glass rapidly cut away its surface. The hand, by turning an electric machine, may thereby charge a battery, whose force will disintegrate steel wire, and send the light of an electric spark to the distance of the moon in a second and one third of time. The voice transmitted through the telephone outstrips in speed "the wingèd couriers of the air." Archimedes proposed theoretically wondrous things with his lever, could he but find a fulcrum.[1]

[1] This speed of transmission by electro-magnetic action appears to have been anticipated by Galen as the medium of communicating thoughts; and most remarkably by Lucretius, in his treatise "De Natura Rerum," published before the Christian era. Addison gives an inter-

Were it practicable to employ the same swift velocity in terrestrial mechanics as in celestial, and to make use of a thread capable of lifting one pound with the swiftness of light (190,000 miles per second), this single thread would serve to transmit 1,800,000 horse-power; being more than sufficient to operate all the machinery in Great Britain.[1]

esting extract from the book of Lucretius in "The Guardian," No. 119, and in "The Spectator," No. 231, as follows :—

"Lucretius gives an account of the correspondence between two friends by the help of a certain loadstone, which had such a virtue in it that, if it touched two needles, one of the needles when so touched began to move, and the other at a great distance moved at the same time, and in the same manner. The two friends, being each of them possessed of one of these needles, made a kind of dial-plate, with the twenty-four letters inscribed thereon, as the hours of the day are marked on a dial-plate. Then they fixed one of the needles on each dial-plate, in such a manner as to turn around without impediment over the four-and-twenty letters. They agreed to separate from one another into distant countries, and withdraw themselves punctually into their closets at a certain hour of the day, and to converse with one another by means of their invention. To write any thing to his friend, he directed his needle to each letter that formed the words, making a little pause at the end of words and sentences, to avoid confusion. The friend at the same time saw his own sympathetic needle moving itself to every letter which the needle of his correspondent pointed at. By this means they talked together, and conveyed their thoughts to one another in an instant over mountains and seas."

Magnetic needles, mounted as described by Lucretius, are now actually used in operating Wheatstone's telegraph for transmitting communications across oceans.

[1] The system of high speed for transmitting power from motors to machines is now introduced with success, and economy in cost of material, by substituting light belts and ropes for massive iron shafts. By doubling the velocity of transmission of action to overcome a uniform resistance (like that of gravitation) in a given time, a fourfold effect is produced; for the double force acts in half the time against half the uniform resistance. Thus by *doubling* the velocity of a ball projected upward, it ascends *fourfold* higher. On this basis is established the rule of the increase of effect being produced in the ratio of the squares of the increased velocities.

CHAPTER XVII.

EXTENT OF SOLAR ACTION TRANSMITTED TO THE SURFACE OF THE EARTH.

THE exciting forces of the planets being uniform, produce a corresponding uniform reaction as sunshine on the surface of the earth. The reflection and radiation of solar light and heat from the earth's surface nearly equalize the degree of excitation in the same localities during a series of years; so that the sunshine is not absorbed permanently within the earth, but is reflected and radiated, sustaining the continual vibration of the surrounding electric ether. The excess of solar excitation incident on the torrid zone is diffused by the molecular vibration of the atmosphere and the ocean-waters toward the polar regions.

The continual transmission of sunshine to the surface of our planet during infinite ages, although reflected and diffused throughout space, has left its impress on the solid rocks by mechanical action and attrition, caused by vibratory impulses imparted to the winds and ocean-waves. The rounded pebbles and the boulders composing beaches and

beds of torrents, and forming strata in the hill-sides and plains, were sculptured by sunshine.

The power of sunshine is shown in the raising of waters from the briny seas, to form inland seas of fresh water, high above the level of the oceans. In order to appreciate the extent of the hydraulic operations in the mechanics of Nature, we must attempt to estimate them.[1]

By concentrating the direct sunshine by lenses or reflectors on a little boiler, sufficient power may be obtained to operate a small steam-engine. It is narrated in history that Archimedes had recourse to reflecting mirrors for setting fire to a hostile fleet in the harbor of Syracuse.

By means of steam-engines, man utilizes the sun-

[1] During a summer excursion to Niagara, in the year 1841, after viewing the Falls, the writer became interested to learn the amount of water-power there developed.

After personally making the attempt to sound the depths of the rapids across the river, and realizing the difficulty and danger by losing an anchor, recourse was had to the professional services of an engineer in that vicinity. An accurate survey was then accomplished of the quantity of water daily flowing in the river. An account and map of this survey was published in Silliman's "Journal of Science," in April, 1844; being the first systematic measurement, if not the only one, made of the volume of water and force of that mighty cataract. By this survey it was found that 701,000 tons of water per minute are continually pouring over the precipice of rocks at Niagara, with a nearly perpendicular descent of 160 feet, and with a mechanical force of 6,800,000 horse-power.

The whole descent from the level of Lake Erie to the sea being about 563 feet, the force of this stream is 24,000,000 horse-power. To this is to be added numerous great tributary rivers in its course, and the descent of the water-fall from lofty clouds in rain-drops. To maintain the flow of this single river there is employed unceasingly nearly three hundred millions horse-power, estimated in foot-pounds. This example affords a faint idea of the extent of solar power constantly exerted in raising water to irrigate our earth.

shine transmitted to the leaves of plants, which is retained in an electro-static condition in the organic formations of fuel. The reaction of the excitation transmitted to this carbonaceous fuel takes place during combustion.

EXCITABILITY OF THE ELECTRIC ETHER OCCUPYING THE SPACES BETWEEN PARTICLES OF WATER, AND OF OTHER SUBSTANCES.

The slightest mechanical disturbance of particles of water puts in motion the all-pervading electric ether, which transfers the mechanical action by its own motion. A basin of water serves as an electrical machine, equally well as the little tank of water with the paddle-wheel used by Mr. Joule and others as a test of the electric excitation denoted heat.

By merely dashing the fingers into the water, or by pouring it from one vessel into another, the excited electric ether causes bubbles to spring up into beautiful hemispheres, which dance over the undulating surface.

Every water-fall excites bubbles to spring up as spray into the air, and reciprocally to repel one another like the pith-balls of electroscopes. The minute bubbles form the mists hovering above cascades, and reflect the sunbeams in overarching rainbows.

The particles of water, being ever-ready electrodes, and freely movable in a liquid state, yield to the slightest vibration of the electric ether. It

is continually changing from a vapory to a liquid state, and from a liquid to the solid polarized state of crystals of ice, yielding to the alternate predominance of the orbital and axial forces in summer and winter. It is on account of this peculiar excitability that water in continual motion is so extensively diffused over our planet.

The vibratory movements of the particles of steam are represented by rapid vibrations of numerous light pith-balls placed beneath a bell-glass, and excited by the electric action transmitted between two brass balls; as in Fig. 58. The pith-balls are first impelled toward the upper brass ball, and then toward the lower one, with such rapidity as to resemble a misty vapor filling the jar.

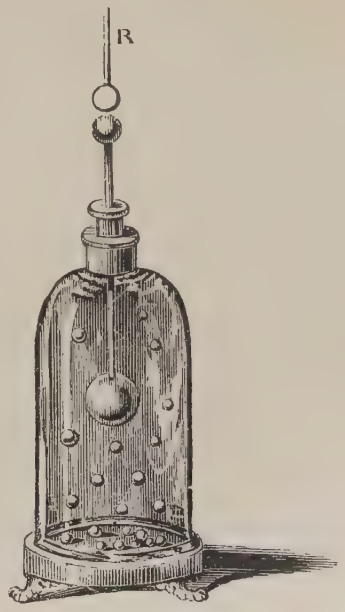

Fig. 58.

The similar quick vibrations of steam in a cylinder beneath a piston drive out the particles of air therefrom, and occupy their places, — impinging against the under side of the piston, and counterbalancing the force of the particles of air impinging upon

the upper side. On stopping the vibration of the particles of steam by a jet of cold water, they collapse, like the balls of electroscopes when the excitation is withdrawn. A cubic foot of steam is thus reduced to occupy the space of only one cubic inch of condensed water, leaving the remainder of the space a *vacuum*. The cubic inch of water, and the additional cold condensing water with the air it contains, is extracted by the air-pump of a condensing engine, while the vibrations of particles of the air continue to act against the upper side of the piston with a resultant force of fifteen pounds on each inch.

The vibrating particles of air, put in motion by the voice, impinge against the little disc or piston of a phonograph, with sufficient force to indent a sheet of tin-foil by every vibrating impulse.

The particles of steam are put into similar vibration by the excitation of heat in a furnace beneath a boiler, with a force acting against the inner sides of the boiler sufficiently to burst it.

By intensifying the excitation of all organic substances by heat, the molecules of hydrogen, oxygen, and nitrogen are made to vibrate to such an extent as to be driven off, leaving the skeleton of all organic formations in carbon, with the organic structure complete,—as manifest in wood charcoal.

By increasing the intensity of vibrations of the residuary charcoal, they excite by contact the adjacent molecules of oxygen in the surrounding

air, sufficiently to become electro-magnetically united with them, so as to form carbonic acid gas by the process of combustion, with the re-development of the light and heat previously transmitted to the leaves of plants to consolidate the charcoal.

THE PLANETARY FORCES DIFFUSED BY THE ELECTRIC ETHER, AS SOURCES OF WIND AND WATER POWER.

To facilitate the general diffusion of vibrations of sunshine put in motion by the revolving planets, the four most readily excitable and freely movable kinds of molecules (oxygen, nitrogen, hydrogen, and carbon), in gaseous states, are selected for the atmospheric covering of the planet. Three-fourth parts of the atmosphere are constituted of nitrogen, combined with nearly one-fourth part of oxygen. About one per cent of the atmosphere is composed of molecules of hydrogen and of carbon combined with oxygen, constituting carbonic-acid gas and watery vapors. The vibrations of sunshine permeate these fluid transparent molecules, and impinge directly on the surface of the earth, without exciting their molecular vibration to the degree recognized as heat; as is manifest by the coldness of the upper regions of the atmosphere. The vibratory action impinging on the terraqueous globe is expended in communicating vibration to its particles, manifested either as heat, or reflected as light and colors.

When a portion of air in contact with a vibrat-

ing body begins to vibrate also, it occupies more space than other surrounding particles of air. Thus rendered specifically lighter, it ascends buoyantly against the action of gravitation. In this simple movement the orbital force predominates. The axial force propels other particles of air into the places left by the ascending particles; and the particles of air thus put in motion impinge against the outspread sails on the water and on the land, and render their impulses available as WIND-POWER.

Beneath the earth's transparent atmosphere, nearly four-fifths of the planet is covered by seas and lakes, composed of eight-ninth parts of molecules of oxygen and one-ninth part of molecules of hydrogen. Particles of water are readily vibrated by sunshine, and, expanded into steamy vapors, they occupy more space than the particles of air. Rendered specifically lighter than the air above them, they buoyantly ascend and are wafted by the winds over the dry lands. After ascending to the cold upper regions of the sky, their vibration being diminished, they become polarized, as minute electro-magnets; with the result of a reciprocal attraction between them, and union in falling rain-drops, which descend from mountains and hill-sides, and flow through the vales on their return to the sea, and are utilized on their way as WATER-POWER.

CHAPTER XVIII.

THE SOLID, LIQUID, AND AËRIFORM CONDITIONS OF MATTER DETERMINED BY THE EXTENT OF ITS MOLECULAR VIBRATION.

THE component particles of the air and waters are the only substances that are commonly in a fluid state. Every kind of elementary matter has been found to be reducible to solid, or crystalline, formations, by bringing the particles together by extreme pressure, while their vibrations are reduced to an extreme degree by frigorific mixtures, as by contact with frozen carbonic-acid gas, at a temperature of 139° below zero of Fahr. The changes of the seasons produce the various changes of water, from crystals to liquid and aëriform states. At the ordinary temperature of the atmosphere mercury remains liquid, but becomes crystallized, or frozen, at 39° below zero of Fahr.

All other solid crystalline metals may be deemed *frozen*, if they are considered relatively to the temperature at which their component molecules become liquefied by heat. As the temperature on the earth's surface is rarely reduced to 39° below the zero of Fahr., molecules of mercury, when not

polarized with molecules of other kinds of elementary substances, exist in a liquid state, and are hence denoted "quicksilver." By artificially intensifying the vibrations of the molecules of quicksilver to 680° Fahr., they yield to the vibration of the electric ether intervening between the molecules, and become expanded and diffused in invisible vapor, floating in the air like steam.

This example of the three states of existence of molecules — in *solid* crystals, in a *liquid* state, and in an *aëriform* state — illustrates the three different conditions of existence of all other kinds of elementary matter; not even excepting the once termed "permanent gases" — such as oxygen, hydrogen, and nitrogen — which have been recently liquefied and solidified by extreme cold and pressure. The boiling point of substances, or their evaporable temperature, appears to indicate the commencement of the extreme molecular vibration, which separates the component parts of substances beyond the range of their reciprocal electro-magnetic attraction.

As previously described, the vibration of the molecules of quicksilver increases uniformly from the freezing to the boiling points; as is evidenced by a uniform expansion in the tubes of thermometers. The increase of vibration of water, developed (as that of all other bodies) by friction and percussion, has been adopted as a useful test of the degree of heat producible by a definite

amount of mechanical action, estimated in foot-pounds. Ice may be melted by the excitation of friction upon its surface; and water may be similarly heated by friction. In this way, Meyer, Joule, and other experimenters have demonstrated that the mechanical force developed by the descent of a weight of seven hundred and seventy-two pounds one foot, excites one degree of heat in a pound of water.

MOLECULAR VIBRATION, CONSTITUTING HEAT, CONSIDERED AS AN EQUIVALENT OF MECHANICAL ACTION IN FOOT-POUNDS.

The increase of the heat of water only one degree, from 212° to 213°, converts it into steam; causing the particles to occupy seventeen hundred fold more space, against an atmospheric pressure of fifteen pounds on each square inch of surface. It has been ascertained also that, after the particles of water are heated to 212°, nine hundred and sixty-seven times more heat is required to raise the same water only *one* more degree, than will raise its temperature from 39° to 40°. The surprising extent of latent vibratory action is shown by multiplying 967 by 772 foot-pounds = 746,524 foot-pounds. The particles of steam, by the intensity of their vibration, displace the particles of the atmosphere (with its reaction of more than one ton on each square foot of surface), and occupy its place.

This 967° of heat remains *latent*, as tested by

the mercury in the bulb of a thermometer. The latent heat of nearly 1000° in steam becomes manifest on its condensation into water, by raising the temperature of about sixfold its weight of water from 50° to 212°.

By this standard of mechanical action for producing vibration of particles of water, estimates have been made, in equivalent foot-pounds, of the amount of heat required to convert a pound of ice into steam. Taking as a basis the force required to raise the temperature of one pound of water 1° Fahr. (Joule's equivalent), the following calculations have been made: —

To excite vibration of the particles of 1 lb. of ice to the degree of liquidity, requires	110,396 foot lbs.
To excite 1 lb. of water from 32° to 212°, that is, 180° of increase of heat × 772 foot lbs., requires .	138,960 foot lbs.
To excite 1 lb. of water at 212° into steam, that is 967 × 772 foot lbs. requires	746,524 foot lbs.
The total mechanical action of	995,880 foot lbs.

is therefore the equivalent of the heat requisite to convert one pound of ice into steam; which being divided by 33,000 = 30¼ horse power.

This theoretical estimate exhibits the wonderful extent of mechanical action transmitted by the vibratory motion of the electric medium as sunshine.

The force required to convert one pound of water from its *gases* to *ice*, has been compared to the descent of a ton down three precipices with a total fall of 2,850 feet.[1]

[1] "Heat as a mode of Motion," p. 168. The "latent heat of evaporation of 1 lb. of water, from and at 212°," is given by Mr. Rankine (Treat-

SUDDEN DISAPPEARANCE OF HEAT FROM CONDENSING STEAM.

Although most of the latent heat of steam becomes manifest by condensation in the pipes of a heating apparatus, yet in operating high-pressure boilers a very sudden and mysterious disappearance occurs; as is manifest by holding the hand in front of the steam issuing from a gauge-cock, with a pressure of seventy pounds to the inch. About thirty years ago an engineer, in reaching out his hand to adjust a leaking valve, felt electric shocks, and saw electric sparks. He narrated the fact to Mr. Armstrong; who constructed a small insulated steam-boiler for experimental use, and in the account of his experiments said: "This boiler excited tenfold more powerful electricity than can be produced by any frictional electric machine hitherto made, giving out sparks more than a foot long." In this way, steam-boilers were introduced to professors of science under the new name of "Hydro-Electric Machines." Armstrong and Faraday ascribed the electric excitation "to the friction of the particles of water

ise on Steam-Engine, p. 300) as "745,812 foot-pounds;" and the "total heat of combustion of one pound of carbon" as "11,194,000 foot-pounds." By this estimate, one pound of coal should evaporate about fifteen pounds of water. Mr. Rankine adopts the estimate of combustion of one pound of hydrogen at 14,500 thermal units of 772 foot-pounds = 47,888,704 foot-pounds, — being fourfold more exciting than one pound of carbon. By ordinary furnaces of steam-engines only a small portion of the theoretical power is practically attained.

against the internal sides of the discharge pipes." It was affirmed at that time that "evaporation and condensation of water, independently of friction, does not produce electric excitation, and we must look to some other source for the origin of lightning."

It occurred to the writer that if properly tested, electric action and reaction being equal, the condensing steam out in the air would exhibit this reaction on pointed wires, like the condensing vapors of thunder-clouds on lightning rods. He remembered also that, on the discharge of steam from volcanoes, lightning amid the vapors is seen above their summits; that atmospheric electricity tips the spears of sentinels on lofty watch-towers; while in storms the masts and spars of vessels are ablaze with the "fires of St. Elmo and St. Anne," to the terror of superstitious sailors.

It had long been known, that on holding the hand in a jet of high-pressure steam from a gauge-

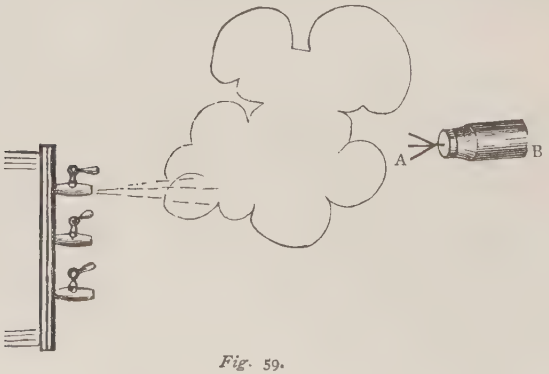

Fig. 59.

cock, Fig. 59, instead of the sensation of scalding heat, rather a cooling breeze was felt. The heat of the steam at 300° Fahr. disappears so instantaneously, that a thermometer held in it indicates only 120°; showing that 180° of the heat has vanished. The question occurred, "What becomes of all the heat of this discharged steam?" This led to a course of experiments. Forked pointed wires were arranged on a metallic rod, as at A, Fig. 59, and the other end of the metallic rod was then inserted through the cover of the electric jar B. This apparatus was held in front of the condensing steam from a boiler, with seventy-five pounds pressure to the inch. The coated glass-jar received and retained the electric excitation transmitted from the steam discharged into the open air. A cold day was selected for more sudden condensation of the steam. On holding the pointed wires in front of the jet of steam, the jar was speedily charged, and transmitted a shock with a bright spark, when touched by the finger. The shocks were not only felt through the arms of the experimenter, but also through the knees and feet of the bystanders on the brick hearth in front of the boilers.[1]

This experiment showed the general diffusion of the electric excitation through the adjacent air. The workmen amused themselves in taking shocks,

[1] An account of the experiment was published in Allen's "Philosophy of Mechanics," p. 38, in 1851.

and the involuntary contraction of their muscles exhibited the actual conversion of steam-power into animal motive-power. While this was a virtual repetition of Franklin's experiment for showing the identity of lightning and electricity from condensing vapors in the air, it further revealed the identity of the latent heat of steam and electricity; and that this motive-power is literally harnessed to our "Lightning Trains."

The sudden disappearance of the extreme heat of a sultry summer-day is accounted for by its conversion into electric action, either by quiet diffusion, or disruptive flashes of lightning.

AMOUNT OF HEAT INSTANTANEOUSLY DISPERSED FROM CONDENSING STEAM.

The total heat in a pound of steam would render a pound of iron red-hot, if it could be transferred to it. The following calculations may show the great extent of latent heat suddenly diffused by the condensation of steam. Estimating the *latent heat* (not indicated by the thermometer) of steam under the ordinary atmospheric pressure to be about 966°, and the additional heat at 300° (the heat of steam under the pressure of seventy-five pounds to the inch), there appear to be 1,266° of heat embodied in the steam experimented upon. If from this extent of heat be deducted the residuary heat, as tested by the thermometer held in the jet from the gauge-cock, at 120° Fahr., there

disappear in the condensation of this discharge 1,146° of heat. This passes off with the speed of light to the upper regions of the sky.[1]

[1] These facts should impress on engineers the importance of employing all available means of preventing the radiation of heat from boilers and cylinders, by non-conducting materials and steam-jacketing. And especially should their attention be called to the possible loss of effective power in working steam expansively, by "cut-off valves" acting at minute portions of the stroke.

If the whole power of steam of seventy-five pounds pressure is instantaneously diffused into electric vibrations and currents, by suddenly expanding into the open air, it becomes a critical question how far this expansive system can be carried advantageously, and without loss by the conversion into electric currents of the heat of expanding steam. The sudden disappearance of the vibratory action of heat from steamy vapors in the sky on a sultry summer-day affords a parallel to the experiment described. The steam rises rapidly from the surface of the oceans to the upper sky, and, being there relieved from compression, expands like the compressed steam discharged from a steam-boiler.

This experiment shows the Protean forms in which the vibration of heat is diffused, not only through the metallic conduction of cylinders, pipes, and shaftings connected with steam-boilers and engines, but also throughout all space. We thus catch a glimpse of the modes in which the force of the planets is diffused through the universal electric ether, and learn what an important part this ether plays in transmitting and modifying their mighty power.

CHAPTER XIX.

MATTER.

THE AXIAL AND ORBITAL FORCE OF THE REVOLVING PLANETS, TRANSMITTED BY THE UNIVERSAL ETHER, IS MODIFIED BY THE MECHANISMS OF SIXTY-SIX KINDS OF ELEMENTARY MOLECULES.

NEWTON defines matter to be "An aggregation of the smallest parts, which are extended, and strongly connected together by an unknown power, . . . which it is the business of experimental philosophy to find out."

Professor Faraday describes a molecule as "something material, having a specific volume; upon which were impressed, at the creation, certain powers, that have given to it from that time to the present the capability of constituting the different kinds of substances, whose properties we discover when a sufficient number of atoms are combined together into molecular groups. . . . The powers of matter we know and recognize in every phenomenon of creation; the absolute matter in none."[1] Buscovich defines molecules to be "centres of forces."

Molecules are aggregations of atoms into little masses, as this term literally signifies.

[1] London and Edinburgh Philosophical Journal, 1844.

That molecules are essentially different in the number, groupings, and arrangements of their atoms, constituting sixty-six kinds of machines, is manifest by their various weights and magnitudes. The lightest kind of molecule, *hydrogen*, has been registered in tables of chemical equivalents at the comparative starting point of 1; the next lightest, *carbon*, 6; *oxygen*, 8; up to a molecule of *gold*, 196; and *lead*, 207.

Each kind of molecule has a different bulk or volume, and each is a perfect machine with a differing atomic structure. Each serves as an electrode and current-changer, receiving, reflecting, modifying, and changing the direction of the electric vibrations and currents, continually transmitted through the universal ether.

These molecules, in turn, are electro-magnetically formed into symmetrical angular crystals, and into more than two hundred thousand species of mechanisms of plants and of animals. The molecules incorporated into the mechanisms of plants serve as food, to be re-incorporated into the mechanisms of living animals, and to vitalize them.

The electric ether being universally diffused, and pervading freely all bodies, does not admit of being weighed, as there seems to be no way of producing an absolute electric vacuum.

The *relative weight* of each of the sixty-six kinds of elementary molecules is ascertained; but the *absolute weight* of each individual molecule is not as-

certained, for the reason that a single molecule is too minute an object to be distinctly seen, or handled.

The following table exhibits a list of the elementary molecules, arranged in alphabetical order, with their relative weights as compared with molecules of hydrogen, adopted as the unit standard of comparison; and hence these comparative weights are denoted "chemical equivalents."

TABLE OF ELEMENTARY SUBSTANCES AND OF THEIR CHEMICAL EQUIVALENTS.

Names.	Abbreviated Symbols.	New Atomic Weights.	Old Atomic Weights.	Names.	Abbreviated Symbols.	New Atomic Weights.	Old Atomic Weights.
Aluminium . .	Al.	27.4	13.7	Manganese . .	Mn.	55.0	27.5
Antimony . . .	Sb.	122.0	122.0	Mercury . . .	Hg.	200.0	100.0
Arsenic	As.	75.0	75.0	Molybdenum,	Mo.	96.0	48.0
Barium	Ba.	137.0	68.5	Nickel	Ni.	59.0	29.5
Beryllium, or	Be.	} 9.0	4.5	Niobium, or	Nb.	} 94.0	94.0
Glucinium . .	Gl.			Columbium . .	Cb.		
Bismuth	Bi.	209.0	209.0	Nitrogen . . .	N.	14.0	14.0
Boron	B.	10.9	10.9	Osmium	Os.	199.0	99.5
Bromine	Br.	80.0	80.0	Oxygen	O.	16.0	8.0
Cadmium . . .	Cd.	112.0	56.0	Palladium . .	Pd.	106.5	53.25
Caesium	Cs.	133.0	133.0	Phosphorus .	P.	31.0	31.0
Calcium	Ca.	40.0	20.0	Platinum . . .	Pt.	197.4	98.7
Carbon	C.	12.0	6.0	Potassium . .	K.	39.11	39 11
Cerium	Ce.	92.0	46.0	Rhodium	Rh.	104.0	52.0
Chlorine . . .	Cl.	35.5	35.5	Rubidium . . .	Rb.	85.5	85.5
Chromium . .	Cr.	52.5	26.25	Ruthenium . .	Ru.	104.0	52.0
Cobalt	Co.	59.0	29.5	Selenium . . .	Se.	79.5	39.75
Columbium, or	Cb.	} 94.0	94.0	Silicon	Si.	28.0	14.0
Niobium	Nb.			Silver	Ag.	108.0	108.0
Copper	Cu.	63.4	31.7	Sodium	Na.	23.0	23.0
Didymium . . .	D.	96.0	48.0	Strontium . .	Sr.	87.5	43.8
Erbium	E.	112.6	–	Sulphur	S.	32.0	16.0
Fluorine . . .	F.	19.0	19.0	Tantalum . . .	Ta.	182.0	182.0
Gallium	–	–	–.	Tellurium . .	Te.	129.0	64.5
Glucinium, or	Gl.	} 9.0	4.5	Terbium	Tr.	148.5	74.2
Beryllium . .	Be.			Thallium . . .	Tl.	204.0	204.0
Gold	Au.	196.0	98.0	Thorium	Th.	231.0	–
Hydrogen . . .	H.	2.0	1.0	Tin	Sn.	118.0	59.0
Indium	In.	114.0	57.0	Titanium . . .	Ti.	50.0	25.0
Iodine	I.	127.0	127.0	Tungsten . . .	W.	184.0	92.0
Iridium	Ir.	197.2	98.6	Uranium . . .	Ur.	120.0	60.0
Iron	Fe.	56.0	28.0	Vanadium . . .	V.	51.0	51.0
Lanthanum .	La.	139.0	69.5	Yttrium	Yt.	92.5	46 25
Lead	Pb.	207.0	103.5	Zinc	Zn.	65.0	32.5
Lithium	Li.	7.0	7.0	Zirconium . .	Zr.	89.5	44.75
Magnesium . .	Mg.	24.3	12.15				

The better to adapt the fractional parts of atomic weights to the standard of a molecule of hydrogen, the latter has been nominally doubled; as shown by the difference in the lists of the old and new symbols in the foregoing table.

The differences of atomic weights and magnitudes of the several kinds of molecules demonstrate their existence as varied atomic structures, or machines; and their several peculiar functions are evidences of intelligence in the Constructor of molecules, rather than in the created molecules themselves. As Professor Dana sagaciously affirms, "Molecular law is the profoundest expression of the Divine will."

Molecules, although too minute to be separately weighed and measured, are large enough to be shadowed by solar microscopes, while moving on a sheet of glass in the process of crystallization.

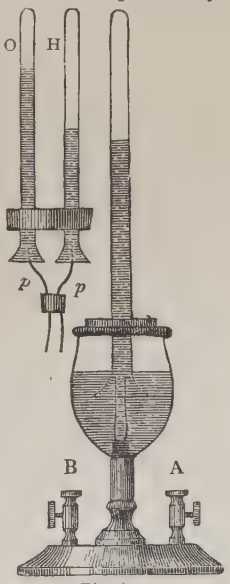

Fig. 60.

The relative weights and magnitudes of the several kinds of molecules are ascertained by decomposing various compound substances, such as water, carbonic-acid gas, &c. In forming compounds, molecules are supposed to be coupled together in pairs. By decomposing a quantity of water, and obtaining its

constituent elements of oxygen and hydrogen in separate gaseous states, as by a voltameter, represented in Fig. 60, the oxygen molecules, rising from one end, or pole of the battery circuit, ascend into the inverted glass-tube O, and the hydrogen into the other tube, H. The respective volumes are indicated by the unshaded portions of the tubes, and may be severally weighed. In this way the *relative* weights and volumes of the oxygen and hydrogen are ascertained. The molecules of hydrogen occupy double the space of the molecules of oxygen, and have only one-eighth the weight.

If the two separated gases be commingled in one tube, and an electric spark be passed through them, they become electro-magnetically reunited, and reproduce water; which weighs as much as the two separate gases. "Tested by the battery poles, substances, considered singly, are neither positive nor negative."

By rendering the molecules of various compound substances freely movable in a liquid state, and placing therein the ends of a conducting-wire connected with a voltaic battery, it is found that one kind of molecules goes to a particular end, or pole, of the battery circuit, and the other kind of molecules to the opposite pole, in a systematic order; commencing with molecules of oxygen, which stands at the head of the list in affinity for the positive pole, being electro-negative to all

other kinds of molecules. Molecules of potassium and nitrogen go to the negative pole, being extremely positive.

These orderly unions and separations of molecules, when subjected to excitation between the two poles of a voltaic battery, show their functions as natural electrical machines.

By pervading the spaces intervening between all the particles of bodies, the electric ether diffuses impulses to every individual part, thus moving the whole. Consequently the number, or quantity, of individual atoms in a body is ascertained by the extent of its gravitating force toward the earth; this being determined by the standard test of counterpoising *weights*. The difference of weights of the several kinds of elementary molecules indicates the various quantities of matter they severally contain.

Each kind being propelled toward one of the two poles of a voltaic battery with a special degree of force, the different kinds of molecules in compound substances are thus separated from each other, or decomposed; as illustrated in the decomposition of water by the voltameter.

The peculiar order in which each kind of molecule goes to a pole of a voltaic circuit, in a regular scale of relationship, shows its subjection to systematic molecular laws.

When the molecules of compound substances are attracted to opposite poles of a voltaic circuit,

they are electro-magnetically separated. Relying on this law, Sir Humphrey Davy proceeded to subject some dissolved potash in a saucer between the two poles of a powerful voltaic battery, and first revealed the surprising fact that this substance is an oxide, or rust, of a shining metal resembling silver.[1]

Following out this mode of detecting the existence of different kinds of molecules in various compound substances, several important metals were discovered; now well known as calcium, magnesium, aluminium, silicium, &c., — the names of these metals being borrowed from the names of the compound substances from which they were obtained.

To designate the family relationships of certain kinds of groupings of atoms into metallic molecules,

A CLASSIFICATION AND DESCRIPTIVE NOMENCLATURE IS INTRODUCED.

To distinguish the newly discovered metals from the early known metals, a simple nomenclature is used, by giving to them the terminal *ium*, — as potassium, calcium, magnesium, aluminium, &c. The only non-metallic substance having the terminal *ium* is selenium.

[1] The simple apparatus originally employed in making this memorable discovery, was courteously exhibited to the writer by his illustrious successor, Professor Faraday, at the Royal Institution in London, in 1852, during an interesting visit to that temple, hallowed by many grand discoveries in Physical Science.

The older known metals are classified in chemical vocabularies by their original Latin names, all having a terminal in *um*, — as *ferrum*, iron; *argentum*, silver; *aurum*, gold; &c.

To the elementary molecules of a doubtful kind is given the terminal *ine*, — as chlorine, bromine, iodine, fluorine, &c.

To designate the unions of molecules in different relative proportions, Latin terms and Greek numerals are used; as *protoxide*, *deutoxide*, or *binoxide*, &c.: the highest combining portion of one kind of molecule with another is designated by the prefix *per;* as the *per*-oxide of iron, *per*-oxide of hydrogen, &c.[1]

In the formation of the atmosphere, which entirely covers the surface of the planet, and of the waters beneath it, that cover nearly four-fifths of the surface of the globe, the four most freely movable and readily excitable kinds of molecules are employed, on account of their superior efficiency.

[1] The latter compound is water, united with an extra proportion of oxygen; similar to the surcharge of soda water with carbonic-acid gas. A surcharge of water with molecules of oxygen is produced by bringing steam into contact with particles of air in "surface condensers" This excess of oxygen being set free by heat in boilers on ocean steamers, where "surface condensers" are used to obtain fresh distilled water for supplying the boilers, it is found that the free oxygen rapidly corrodes the iron plates. This difficulty, which countervails the theoretical advantage of the use of fresh water in marine boilers, might probably be obviated by passing the condensed water through a tube containing waste chips of iron turnings, with which oxygen combines with almost explosive rapidity. This may be tested by dropping iron filings into water, containing a surcharge of oxygen, in the state of "peroxide of hydrogen."

The ancient philosophers classified the material world into four elementary divisions, — fire, air, earth, and water. They taught "the existence of a universally diffused ethereal medium, pervading all things, and manifest as *fire* when put in motion." This ethereal medium they placed at the head of elementary substances, as occupying all space not occupied by other matter, and as being in continual motion.

These unceasing motions we can trace, through the momentum of the vast solar systems, to the power of their "Unknown God."

CHAPTER XX.

FUNCTIONS OF MOLECULES OF OXYGEN, CARBON, HYDROGEN, AND NITROGEN, AS ELECTRICAL MACHINES.

THE molecules of oxygen take precedence of all others, both in comparative quantity and facility of motion by excitation. They constitute nearly half of the matter of our planet, including eight-ninths of the weight of waters, — one-fourth of the weight of the atmosphere, — and a large part of the rocks, sands, and clays. The molecules of oxygen are kept ever moving in the air and waters, from region to region over the earth, forming unions with other kinds of molecules, and dissevering them; according to their changing states of excitation, as by sunshine and shade, heat and cold.

Oxygen gas is readily obtained by disuniting it from other kinds of molecules; as by the decomposition of water and of various metallic oxides. For experimental purposes it is commonly procured by heating chloride of potash in a retort. The influence of molecules of oxygen in producing acids, obtained for them their characteristic name; from the two Greek words, oxus, *acid*, and

GENNAO, *I produce.* These molecules are distinguished for producing light and heat, by uniting with most other kinds of elementary molecules, as iron, gold, zinc, &c.; but more especially with molecules of carbon. Their rapid electro-magnetic union with substances used as fuel is denoted combustion; a slower union of oxygen with other substances in voltaic cells, or by fermentation and putrefaction, is called chemical decomposition.

The molecules of oxygen and hydrogen unite with intense activity in the process of combustion, and an equally intense excitation is requisite to separate them,—as is shown by a voltameter in the decomposition of water.

To these very important functions of molecules of oxygen we shall have frequent occasion to recur, in sketching some of the functions of carbon, hydrogen, and nitrogen, in their various connections with oxygen, in organic formations of plants and animals.

MOLECULES OF CARBON.

Next in importance to molecules of oxygen are molecules of carbon. If the former be deemed the Jupiter of elementary substances, carbon may be deemed the Juno.

The molecules of carbon in a diamond, by their strong electro-magnetic union, overpower the electro-magnetic unions of all other kinds of molecules, which they sever by their cutting points.

The addition of only one molecule of carbon to a hundred molecules of iron, carries with it a peculiar hardness and cutting property by converting the iron into steel, and doubles the value of the iron, to which it imparts permanent magnetic powers. The addition of about fifty per cent of molecules of carbon to the elements composing water (hydrogen and oxygen), characterizes the substance of saps, fruits, and grains serving as *food*, to be reorganized into the bodies of living animals. The very same molecules of carbon, excited by sunshine on the leaves of plants, carry with them their tenacious properties in the formation of fibres of hemp, cotton, flax, jute, &c. Other kinds of merchandise, especially valued for peculiar characteristics, are composed of carbon in variously proportioned combination with the three other kinds of molecules, — oxygen, hydrogen, and nitrogen. These compounds develop the several peculiar properties of wood, fruits, grains, grasses, tobacco, opium, drugs and medicines, food and fuel.

Carbon united with oxygen, as carbonic-acid gas, combines with molecules of the metal calcium in the formation of lime-rocks and marbles, of the bony skeletons of animals, and even of the translucent and iridescent pearls. One half the weight of dried flesh and blood consists of molecules of pure carbon or charcoal; as also one quarter of the weight of all dried wood. This is shown in

the process of driving off the other three kinds of molecules by heat.

The extent to which this process of carbonization has been carried on during the geological heating of our planet is manifest in the vast beds of mineral coal, organized by antediluvian sunshine on the leaves of plants. Indeed, molecules of carbon, oxygen, hydrogen, and nitrogen, combined by the solar excitation transmitted to the outspread leaves of plants, constitute the substances most essential for sustaining life, and those whose possession is prized as individual and national wealth.

MOLECULES OF HYDROGEN.

Molecules of pure hydrogen, in the form of gas, rarely exist; being generally found in a state of union with oxygen as water, and with other kinds of molecules.

It is used in balloons on account of its great buoyancy. A triple alliance of molecules of hydrogen, oxygen, and carbon imparts a wonderful diversity of properties to numerous organic substances, as wood, vegetable oil, animal flesh and fat, &c.

One of the most remarkable changes in the properties of hydrogen molecules is their conversion into acids, when united with oxygen; and into alkaloids, when combined with nitrogen, — as in the formation of ammonia.

Equal measures of hydrogen and chlorine gases,

when commingled, form such an unstable mixture that a gleam of sunshine upon them will cause an explosion, — like that produced by the union of molecules of hydrogen and oxygen by an electric spark.

Numerous changes of characteristic properties of organic compounds are produced by varying the proportionate quantities of the molecules of hydrogen and carbon.

MOLECULES OF NITROGEN.

The molecules of nitrogen are manifestly employed for partially neutralizing and modifying the transmission of electro-mechanical action and reaction between other kinds of molecules. Were not the atmosphere diluted with three-quarter parts of molecules of nitrogen, the intensity of the electro-magnetic attraction of the pure molecules of oxygen for other kinds of molecules would produce a conflagration of surrounding bodies. Even the grate bars of a furnace would burn with a more brilliant light and intense heat than any fuel ordinarily consumed therein.

If the proportion of the molecules of nitrogen and oxygen in the atmosphere — composed, by weight, of nitrogen seventy-seven and oxygen twenty-three — be reversed to oxygen seventy-seven and nitrogen twenty-three, nitric acid would be developed; which is the most powerful re-agent employed by chemists for decomposing compound substances.

Organic substances composed of carbon, united with hydrogen and oxygen in the proportions constituting water (such as cotton, oil, and animal fat), if impregnated with nitrogen, produce explosive substances, — gun-cotton, nitro-glycerine, dynamite, &c.

A remarkably sudden development of reaction ensues, when the molecules of nitrogen predominate in a compound with carbon, — as in prussic, or hydrocyanic acid, — in the proportions of

Nitrogen	14 = 51.85	by weight	Prussic Acid.
Carbon	12 = 44.55	„	
Hydrogen	1 = 3.70	„	

When this unstable compound of prussic acid is taken into the stomach, the carbon, instead of being slowly dissolved into chyle by the usual process of digestion, unites with the oxygen of liquids in the stomach with nitrogenous rapidity; and, probably reversing the direction of the electric currents through the sensorial nerves, produces an instantaneous cessation of nervous sensibility, and the suspension of the vital powers.[1]

The presence of the molecules of nitrogen in the compound substance ammonia (NH_3) hastens

[1] If the nitrogenous compound of prussic acid be taken into the stomach in a considerable quantity, a nervous paralysis ensues, until the blood coagulates and death takes place; but if the quantity be small, only a temporary nervous insensibility follows, — as was verified by the writer in an attempt to make way with an obnoxious cat. The animal apparently became dead in an instant, and was decently buried in a distant ash-pit. After a time, he reappeared on the scene like Banquo's ghost, and, looking up reproachfully, began to shake off his shroud of ashes!

greatly the decomposition of all organic substances used for fertilizers in agriculture.

ISOMERIC BODIES.

Isomeric bodies do not always manifest the same peculiar properties. The oil of turpentine, of lemon, and of roses, being analyzed, appear to be composed of the same identical proportions; and yet they transmit different reactions through the sensorial nerves.

Chemists have tried to convert resin into butter on isomeric principles; "but the scent of the *resin* will hang round it still." Similar attempts continue to be made to convert oils and fat into butter.

The reflection of colors from the surface of isomeric bodies appears to be remarkably uniform; as discovered by Graeby and Silberman, in substituting the colors called "Aniline," derived from coal-tar, for the coloring matter in madder, now generally used for dyeing cloths red, purple, and violet.

Not only do different kinds of molecules reflect vibrations of light with different intensity, corresponding to a chromatic scale of colors, but also peculiar dark lines, or markings (discovered by Frauenhöffer), on which is now based what is called "Spectrum Analysis." This is the most delicate known test for determining the kinds of molecules contained in compound substances, and

the only test of the composition of the heavenly bodies. The excitation of the flame of a blow-pipe, directed upon specimens of metals and ores laid on a piece of charcoal, affords a beautiful exhibition of colors developed by different kinds of molecules. The presence of molecules of strontium, copper, soda, &c., modify the vibrations of light and colors transmitted to the eye.

FORMATION OF MOLECULES INTO CRYSTALS.

The orderly and systematic movements of molecules during the process of crystallization are wonderfully displayed by the magnifying powers of optical instruments. Their shadowy outlines appear moving over a white sheet of canvas in files, like drilled soldiers passing in review. The gradual evaporation of a liquid solution of salts, spread on a transparent sheet of glass, brings the molecules toward each other within the range of their reciprocal electro-magnetic forces; when they successively start forward to their proper places to form beautiful symmetrical crystals, without any of the jostlings or mistakes observable in the ranks at a militia muster. So orderly are the movements, that the molecules seem to be endowed with self-motive and self-directive powers. Expressions of surprise and admiration are often heard from spectators, who for the first time behold the wonderful automatic movements of molecules in the process of crystallization.

The symmetrical electro-magnetic unions of particles of water are familiarly exhibited in the feathery crystals of falling snow (Fig. 61). It will be noticed that the arrangements of its molecules are all hexagonal. Different kinds of molecules have other different and peculiar arrangements, some of which are delineated in Fig. 62, showing their characteristic forms of crystalline polarization. The shapes of crystals are deemed by chemists to be indications of the peculiar kinds of molecules distinguishing them.

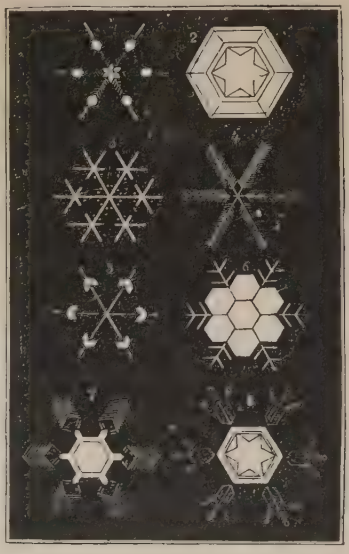

Fig. 61.

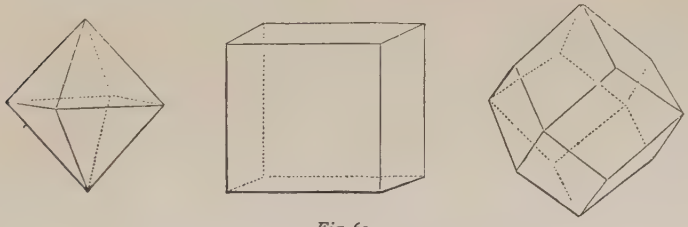

Fig. 62.

The hexagonal lines of crystals of water are familiarly seen in the frost-work on window-panes, produced by the axial rotation that predominates during the withdrawal of solar reaction in wintry nights, as previously described. So mathematically

exact are the polygonal shapes of crystals, that they appear to be works of art, rather than natural formations. Feeble as may appear the movements of molecules visible under the microscope, yet the power that moves them is more forcible than that of gunpowder; for the strongest cannon are burst by the expansion of particles of water, on reducing the temperature a few degrees below the freezing point. Thus the terrestrial currents that produce a change of particles of water into ice-crystals exceed the force developed by the vibrations excited by 1000° of heat.

The angular and symmetrical forms of crystals appear to result from the peculiar shape of each kind of molecule, these molecules fitting to each other electro-magnetically according to the angles of their various sides. A cube is formed by molecules arranged with rectangular sides, as is manifest from the cleavages. The various angles at which they unite may be indicated by sprinkling on a loadstone small nails with angular heads. The sloping sides of the heads are drawn to the sides of the loadstone, giving corresponding direction to the nails, which bristle out in various directions, as represented in Fig. 63.[1]

The polarization of watery sap in the vesicles of

[1] A speculative philosopher, the Rev. J. G. McVicar, LL.D., has fancifully depicted various forms of molecules, adapting them to fit together in different combinations, — some of these curious forms resembling the hour-glass-shaped waists of the belles of ancient times.

the leaves of plants crystallizes it into ice, and bursts them like bottles containing freezing water; as occurs in autumn through the waning vibrations of sunshine, when the terrestrial currents predominate. The leaves of evergreens escape destruction and retain perennial verdure because the vesicles are filled with unpolarized *oils*.

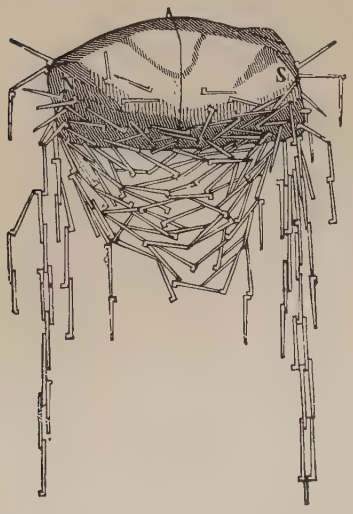

Fig. 63.

In the preceding figure, ordinary flat-headed iron tack nails are represented. If the heads are made of a sloping shape, they are held to the surface in diagonal directions, as if fitted together by mitre-joints to form hexagonal, octagonal, and other symmetrical shapes.

CHAPTER XXI.

PECULIAR QUALITIES OF COMPOUND SUBSTANCES DEVELOPED BY VARIOUS RELATIVE PROPORTIONS OF THE SAME KINDS OF MOLECULES.

THE following table exhibits the remarkable difference in the characteristic properties of well known compound substances, developed by increasing the number of molecules of carbon and hydrogen, by pairs, from four to thirty-four, with a *constant* quantity of four molecules of oxygen.

VINEGAR, BUTTER, VEGETABLE OILS, AND FAT PRODUCED BY VARYING THE RELATIVE PROPORTIONS OF CARBON, HYDROGEN, AND OXYGEN.

No.	Union of Molecules of			Compound Substances Produced.			
	Carb.	Hydro	Oxy.				
1	4	4	4	Vinegar . . .	or	Acetic . . .	Acid.
2	6	6	4	Burnt Sugar .	,,	Meta-cetonic .	,,
3	8	8	4	Butter . . .	,,	Butyric . . .	,,
4	10	10	4	Vegetable Oil .	,,	Valerianic . .	,,
5	12	12	4	,, ,, .	,,	Caproic . . .	,,
6	14	14	4	,, ,, .	,,	Oenan-thylic .	,,
7	16	16	4	,, ,, .	,,	Caprytic . . .	,,
8	18	18	4	,, ,, .	,,	Pelargonic . .	,,
9	20	20	4	,, ,, .	,,	Capric . . .	,,
10	–	–	–				
11	24	24	4	Bayberry Tallow	,,	Lauric . . .	,,
12	26	26	4	Cocoanut Oil .	,,	Coconic . . .	,,
13	28	28	4	Nutmeg Oil . .	,,	Myristic . . .	,,
14	–	–	–				
15	32	32	4	Palm Oil . .	,,	Palmitic . . .	,,
16	34	34	4	Animal Fat . .	,,	Margaric . .	,,

The presence of four molecules of oxygen in each of these groupings appears to determine their *acid* property.

The grouping of four molecules of carbon with six of hydrogen and only one of oxygen is essential to the development of the exciting powers of alcohol, which takes precedence of all other substances for general use in stimulating the vital powers; even to the destruction of body and mind. By increasing the carbon from four to ten, with eight of hydrogen and one of nitrogen, another stimulating vegetable substance — nicotine — is produced.

By combination in other various proportions of the four kinds of molecules, — carbon, hydrogen, oxygen, and nitrogen, — the peculiar powers of numerous drugs and medicines are developed, as shown comparatively in the following table: —

PROPERTIES OF DRUGS AND MEDICINES DEVELOPED BY VARIED MOLECULAR GROUPINGS.

Mercantile Names.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Chem. Names.
Opium	40	20	1	12	Narcotine.
Quinine . . .	22	12	2	1	Quinine.
Tobacco . . .	10	8	0	1	Nicotine.
Alcohol . . .	4	6	1	0	Alcohol.

This wonderful diversity of characteristic properties is brought about by varied combinations of only a few of the sixty-six different kinds of elementary molecules. All the various qualities of food for exciting the vital powers, — of deadly poisons terminating them, — of salutary drugs and healing medicines, are developed through the instrumen-

tality of groupings of molecules, as machines for modifying the excitation and diffusion of electro-mechanical action induced by the planetary forces.

COMPARATIVE QUANTITIES OF ELEMENTARY MOLECULES GROUPED IN THE ORGANISMS OF PLANTS AND ANIMALS.

Constituents of Plants and Animals.	Albumen.		Fibrine.		Caseine.	
	Plants. Wheat.	Animals. Blood, Eggs.	Plants. Sap.	Animals. Muscles.	Plants. Various Seeds.	Animals. Milk and Cheese.
Carbon	54.71	54.84	54.60	54.56	54.13	54.96
Nitrogen	15.02	15.83	15.81	15.72	15.67	15.80
Hydrogen	7.13	7.09	7.30	6.90	7.15	7.09
Oxygen . . . 22.12 Sulphur . . . .37 Phosphorus, .35 Lime 30	23.14	22.24	22.29	22.82	23.03	22.24
	100.	100.	100.	100.	100.	100.

The vegetable albumen of wheat, constituting one of the principal kinds of food of man, and the animal albumen of meat, muscle, and eggs, are nearly identical.

Albumen — composed of molecules of carbon, hydrogen, oxygen, and nitrogen, with a little lime, sulphur, and phosphorus — is first organized by sunshine on the leaves of plants into the compound substances constituting *food* for animals; which is reorganized into living mechanisms. As affirmed by Liebig, "Albumen is the true starting point of all animal tissues." From albumen in an egg, all the feathers, bones, flesh, and horny bill of a complete bird are developed. A little

iron is present in the blood, serving to impart to it a red color, and a little silicon and potash are found in the solid skeleton parts of plants and animals. These kinds of molecules are scientifically combined together to form the mechanisms of living plants, and of the animals in which finite intelligences on earth for a brief time have local habitations. The immediate seat of human intelligence, the brain, according to Fremy, is composed of seven parts of albumen and five of fatty matter, with a little phosphorus and sulphur, and the remaining seventy-five parts of water. In this arrangement of molecules in cells, tubes, and conducting nerves, constituting the brain, human intelligence is enthroned, and by it receives and transmits communications from and to the objects of the external world.

As each individual molecule serves as an electrical machine for developing a peculiar reaction, so each kind of groupings of molecules similarly serves to develop a peculiar electro-mechanical reaction, which constitutes the characteristic properties of various compound substances.

The annexed table exhibits the proportionate quantities of each of the four most excitable kinds of elementary molecules, which are utilized as *food* for developing plants and animals, animal warmth and motive-power; and also as *fuel* for developing heat, light, and the motive-power of steam.

RELATIVE PROPORTIONS OF THE FOUR KINDS OF FLUID ATMOSPHERIC MOLECULES, WHICH ENTER INTO THE ORGANIC FORMATIONS OF FOOD AND FUEL.

Table of Vegetable Organic Formations Utilized as Food and Fuel.

Food and Fuel.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ashes, &c.	Total.
Wheat	46.10	5.80	43.04	2.03	2.04	100
Oats	50.70	6.00	37.30	3.00	4.	100
Dry Hay	49.	5.63	36.71	1.84	6.82	100
Dried Potatoes .	44.	5.80	44.70	1.50	4.	100
Dried Turnips .	43.	5.40	42.30	1.70	7.60	100
Olive Oil	77.21	13.36	9.47	–	–	100
Butter	40.	40.	20.	–	–	100
Turpentine . . .	88.46	11.54	–	–	–	100
Whale Oil	79.	11.54	9.	–	–	100
Hog's Fat	79.	11.54	10.	–	–	100
Human Fat . . .	79.	11.54	10.	–	–	100
Blood, Flesh . .	73.	7.	20.	–	3.	100
Wood, or Lignine	50.	5.	42.	–	–	100
Bituminous Coal	70.	6.25	12.50	6.25	5.	100
Anthracite Coal	89.	3.	4.	6.25	3.	100

The *ashes* are constituted of potash, silex, lime, and sulphur.

CHAPTER XXII.

PLANTS AS ELECTRIC MACHINES.

MATTER has been classified into two grand divisions, — ORGANIC and INORGANIC.

By microscopic examination of the structure of plants, and also of animals, they are found to be composed of congeries of tubes, resembling the multitude of pipes in an organ: hence the term, *organic*, originated in contradistinction to the grouping of molecules into crystals by electro-magnetism, denoted *inorganic* formations.

The union of molecules by electro-magnetism in liquid, and aëriform, and various other states, without any crystalline structure, is designated AMORPHOUS.

The total number and quantity of organic remains on the surface and in the strata of the earth are inconceivably great. Nearly half of the earth's surface is covered with animal and vegetable fossiliferous deposits: many of the latter are several thousand feet in thickness. They abound on mountains at an elevation of more than sixteen thousand feet above the level of the sea, — in strata on the Himalayas and the Andes, — and are found at the bottom of the ocean at a greater number of

feet below its level. There are far more beings entombed within the earth than are alive upon its surface.

The name of "Plant" is derived from PLANTA, the *sole of the foot*, — as if plants stood on one foot while holding out their leaves and blossoms; denoted *petals*, from the Greek PETALOS, *outspread*.

The leaves of plants over the whole surface of the earth, while excited by sunshine, like the excited plates or leaves of a voltaic battery, are specially adapted to decompose water and carbonic-acid gas; so that plants are really electric machines.

As the ebbing and flowing tidal waves of the electric ether, excited by artificial revolving magnets, are converted by "current-changers" into currents moving in a uniform direction, so there are over a quarter of a million of different kinds of natural mechanisms of plants subjected to solar excitation, which convert the vibrations of light and heat into thermo-electric currents through the sap pores, in a circuit between the leaves and the roots buried in the cool moist earth.

As the plates or leaves of zinc, excited by acids in the cells of voltaic batteries, remain cool while converting vibrations into electric currents, so, during a like natural process, the leaves of all plants remain cool, while decomposing the carbonic-acid gas and water brought to them by zephyrs and rain-drops as their appropriate food.

Plants being composed of electro-magnetic molecules are consequently, in their groupings and masses, electro-magnetic. The organs of living plants are galvanic batteries, transmitting and modifying solar vibrations. The excitation of electricity is going on in every movement of organic as well as inorganic matter, and a disturbance of electric equilibrium is continually taking place in each molecule of the living plant and animal.

By the law of compensating movements a speedy or gradual restoration of the disturbed equilibrium is effected, by what is denoted

CHEMICAL DECOMPOSITION.

A chemical analysis of plants shows that their organic structures are composed of the same elementary molecules as the atmosphere and water, — oxygen, hydrogen, carbon, and nitrogen.

The establishment of life-power in connection with molecules grouped into the germs of organic formations of plants, may be ascribed to the absolute will of the great First Cause, as it is beyond the scope of science. "And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit-tree yielding fruit after his kind, whose seed is in itself upon the earth; and it was so."

Observation teaches us that every static and dynamic condition of the groupings of such molecules, both in plants and animals, is governed by mechanical laws.

The two great processes in the growth of plants are the decomposition of carbonic-acid gas, and the electro-plating of molecules of carbon upon model germs of new plants.

In electro-plating, the magneto-electric machine is formed of magnets revolving around a central axis, with a current-changer annexed. Scientific knowledge is shown in the construction of the machine, and artistic skill is required for the production of original and beautiful models.

So, in the natural process of electro-plating, the motive-power is the magneto-electric machine of the solar system; the current-changers are the leaves of plants; and the original models to be electro-plated are the embryo germs in seed-vessels.

The decomposition of carbonic-acid gas, and the transfer of the carbon, molecule by molecule, through the liquid solution of sap, into the organic formations of plants, renders our planet (among other marvels) a great electro-plating machine, continually employed in developing the embryo germs of plants into strength and growth.

Omniscience and omnipotence are manifested in the original conception and construction, and in the graceful and elaborate forms of the model germs.

Plants are found which have received the descriptive names of the *bee* and *fly* plants. Others resemble hoods, helmets, arrow-heads, slippers,

horsetails, pitchers with nicely fitted lids automatically opening in wet and closing in dry weather. On the parched plains of Ceylon, birds sip water therefrom.

The Passion-flower is so called from a resemblance to the sacred emblems of the crucifixion. Many of these flowers resemble works of art. A plant in the regions of Panama has the form of a dove with outspread wings and drooping head, as represented by the old masters in the baptism of our Saviour. The cyenoche plant of Surinam has the graceful outline of a swan, with its curving neck and swelling breast. One of these flower-birds shows a head with a white crest curved back, as if to plume its feathers.

There is no limit to these fanciful forms. The germs of plants, like those of animals, are developed by sexual organs of stamens and pistils, and are classed together in families.

They appear to manifest parental rejoicing on the birthday of each new-born germ, by hanging out blossoms, like painted and perfumed banners pendent from twigs and stems, and resplendent in the sunshine.

The seeds of certain plants are disseminated by winds and waters. The cocoanut, a little argonaut, provisioned with milk and water for a sea voyage, freighted with a life of its own, with its magnetic and diamagnetic currents, impelled by winds and tides, floats over the water, reaching at

length some coral island in mid-ocean. Dashed on the strand by the waves, it is saved from fracture by its hard covering. The spongy husk absorbs the rains. The rootlets descend through two apertures in the shell; the sprout ascends through a third; and speedily a young palm tree spreads its broad leaf to the vibrations of the solar light and heat.

If this incipient palm tree, by its self-directive powers, anticipates geological formations, provisions its craft for a sea voyage, and takes possession of an emerging coral isle, it as much surpasses man in intelligence as in physical growth.

Among the dense crowds of growing plants, as in the ranks of social life, there is the same aspiring to overtop each other, the same laying up of little stores for the future wants of their offspring, and the same appropriation of them by others, not their progeny.

Plants extend their roots to reach substances which are their appropriate food. The molecules of carbonic-acid gas, in permeating the soil, are attracted by the negative points of the rootlets, as by the pole in a galvanic circuit in electro-plating with molecules of gold or silver. By the continued deposit of molecules of carbon on the ends of the rootlets in the direction of the advancing current of carbonic-acid gas, the accretions naturally take place in the direction of the decomposing body, from which the gas issues.

If a body absorbs carbonic-acid gas and gives out oxygen, it belongs to the *vegetable* kingdom; if it absorbs oxygen and gives out carbonic-acid gas, it belongs to the *animal* kingdom. In this way the difference is tested.

Becquerel says that electric currents may be actually detected between the parts about the stems and the opposite parts of various kinds of fruit.

"Certain vegetable organizations, especially those of an orange color, — such as the marigold, orange lily, monkshood, and indian pink, — emit at intervals of several minutes two or three flashes of light in quick succession; and when several flowers in the same place emitted their light together, it could be seen at a considerable distance. This phenomenon was noticed in July and August, when the sky was clear."

There is no doubt that light is emitted by many fungi while germinating, and in some cases to a very considerable extent. An authentic instance is recorded, in Gardner's "Travels in Brazil," of a fungus which grew on the decaying leaves of a dwarf palm. "The whole plant gives out at night a bright phosphorescent light of a pale greenish hue, similar to that emitted by the larger fire-flies. The light given out by a few of these fungi in a dark room was sufficient to read by."[1]

"No phosphorescence is perceived in the dead plant." Pouillet also proved experimentally that

[1] Carpenter's Physiology.

the ordinary processes of vegetable growth are attended with a disturbance of electric equilibrium, which is manifested when the bodies in which it takes place are effectually insulated. "Several pots filled with earth, and containing different seeds, were placed on an insulated stand in a room, the air of which was kept dry by quick-lime; and the stand was placed in connection with a condensing electrometer. During germination no electric disturbance was manifested; but the seeds had scarcely sprouted when signs of it were evident; and when the young plants were in a complete state of growth, they separated the gold leaves of the electrometer half an inch from each other."

It was calculated by him that a vegetating surface of one hundred square metres in extent produces in a day more electricity than would be sufficient to charge the strongest battery; and he not unreasonably considered that the growth of plants may be one of the most constant and powerful sources of atmospheric electricity.

The disengagement of vapor from the surface of the leaves alone would be sufficient to produce such a disturbance, — as the fluid from which it is given off is always charged with saline and other ingredients; and the gaseous changes which are effected by the leaves upon the oxygen and carbonic acid of the atmosphere, may be regarded as additional sources of its development.

During the various processes of decomposition and recomposition, which take place in the assimilation of the vegetable juices, we should expect that electric equilibrium would be constantly disturbed and restored.

"Of this, the following facts, amongst others, appear to be sufficient evidence. If a wire be placed in apposition with the bark of a growing plant, and another be passed into the pith, contrary electrical states are indicated when they are applied to an electrometer. If platinum wires be passed into the two extremities of a fruit, they also will be found to present opposite conditions." "In some fruits, as the apple and pear, the stalk is negative, the eye positive; while in such as the peach and apricot a contrary state exists. If a prune be divided equatorially, and the juice be squeezed from its two halves into separate vessels, its portions will in like manner indicate opposite electrical states, although no difference can be perceived in their chemical qualities."[1]

[1] Annales de Chimie, tom. 57. Carpenter's Physiology, p. 462.

CHAPTER XXIII.

ANIMALS AS ELECTRIC MACHINES.

THE extraordinary electrical powers possessed by certain fishes was noticed in the earliest records of science, by Aristotle, Pliny, and other ancient authors. After the discovery of the electrical jar and the shocks produced thereby, the similarity of the sensation was so striking as to obtain for them the name of "electrical" fishes.

In the torpedo, there are a great number of small membranous cells arranged like those of a honeycomb, as shown in Fig. 64.

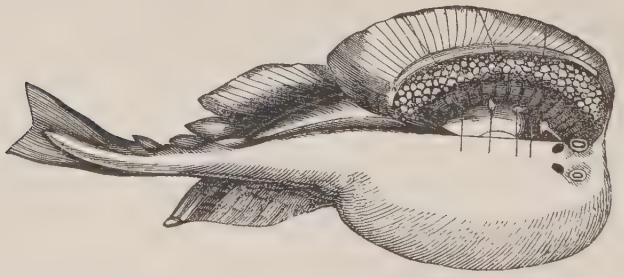

Fig. 64.

These cells are filled with a mucous substance, and are furnished with tissues of nerves. No use can be imagined for this peculiar arrangement of cells, unless it be for the purpose of a galvanic

battery. The electric circuit is directed between the surface of the belly and that of the back. It is said that "there are eleven hundred and eighty-two of these cells in a single organ, all connected by nerves, — which are electrodes, like conducting wires. When the nerves are cut off, all transmission of electricity ceases; otherwise this transmission continues after the heart of the animal has been cut out and his skin stripped off."

"The shocks given are subject to the will of the torpedo; for he may be touched many times without giving one. But when irritated, the violence of the shock will be redoubled."

Electric sparks have been rendered visible by Matteucci, who applied to the fish two metallic armatures, having arranged two slips of gold-leaf very near each other in the connecting circuit. On irritating the torpedo, a brilliant spark was seen between them.

"The electrical lobes of the brain of the torpedo are larger than the whole remainder of that organ; and the density of the electrical nerves is greater than that of the others."

"The electric force is developed in the electric organ by a disturbance of its equilibrium, consequent upon nervous agency. Such a disturbance may be conceived to take place in every one of those minute cells, into which the prism is divided by transverse partitions. By the multiplication of

such cells in each prism, a *pile* would be produced, at the two extremes of which the greatest differences in the electric conditions would be found; and the intensity of the discharge would thus depend upon the number of elements in the pile; while its quantity would be proportional to the multiplication of the separate prisms.

"This is precisely what holds good in Nature; for the electric discharge of the gymnotus is far more intense than that of the torpedo, as might be expected from the multiplication of its cells; so that, according to Professor Faraday, 'a single medium discharge from this animal gives a shock equal to that of a battery of fifteen Leyden jars, containing 3500 square inches, charged to its highest degree.' Further evidence, that the force which enables electric fishes to give sensible manifestations of electricity is the same as that which excites contraction when transmitted to the muscles, is derived from the close conformity between the conditions under which the two phenomena respectively occur. The connection of the organs, specially appropriated to each of these actions, with the nervous system, — the dependence of their functions upon the integrity of this connection, and upon the will of the animal, — the influence of stimulation applied to the nervous centres or trunks, — the effect of ligature or section of the nerve, and the results of poisonous agents, — are all so remarkably analogous in the two cases,

that it seems scarcely possible to refuse assent to the proposition, that the nervous power is the agent which is instrumental in producing both sets of phenomena."[1]

Humboldt[2] says that "some of the South American gymnoti were from five to six English feet in length, and three and one-half inches in diameter. The rows of little yellow spots are symmetrically arranged along the back, from the head to the end of the tail, every spot surrounding an excreting duct. The skin of the animal is coated with a slimy matter, which, as tested by Volta, serves to conduct electricity twenty or thirty times better than water."

Mr. Sidney says of an eel in the Royal Institute in London: "On giving the animal a good shaking with the wires he became angry, emitting a discharge which caused an electric spark to pass between a knob and piece of gold-leaf, which was partially burned thereby. Compound substances were decomposed, steel needles were magnetized, and other phenomena were produced similar to those presented by a regular galvanic apparatus." He adds that "Captain Basil Hall was laid prostrate on the floor by a shock."

In an experiment made with the same eel, by Mr. Noad, a fine conducting-wire was made red hot by the electric discharges. A defiant life-

[1] Carpenter's Physiology, pp. 465, 470.
[2] Annales de Chimie, tom. 11, p. 255.

guardsman came down upon the boards with the clang of cuirass and sabre, to the great amusement of the spectators.

Faraday, in summing up the powers of electrical fishes, observes: "I cannot refrain from pointing out the enormous absolute quantity of electricity which the animal must put in circulation at each effort. It is doubtful if any common electrical machine has as yet been able to supply electricity sufficient, in a reasonable time, to cause true electro-chemical decomposition of water; yet the current from a fish has done it.

"The electrical discharges, each of which endures for a sensible period of time, resemble more those of a voltaic apparatus, intermittent in its action, than those of a Leyden jar, which make their transit in an instant."

Henry Letheby[1] states that "there are arranged along the interior of the body of the electric eel two pairs of electric organs, composed of aggregations of regular cells of membranous tissues, extending obliquely from within outward, and containing a peculiar albumino-gelatinous fluid. The dimensions of these cells are about two hundred in the space of an inch. The entire number of cells in the batteries on both sides is about five hundred and fifty thousand. There are good reasons for believing that the brain and spinal cord are the seat of power, and that the battery is no other

[1] Transactions of London Electrical Society, p. 367.

than an apparatus for accumulating that power, as electricity is accumulated in Leyden jars. The power exists only during life, and while the brain is active; and is voluntary and dependent on the integrity [perfect conductibility] of the nerves. Direct irritation of the brain will effect a shock."

Humboldt narrates a conflict he saw in South America between electric eels and horses driven into the water among them, purposely to exhaust their muscular power. "Gradually the impetuosity of the unequal conflict diminished, and the exhausted eels dispersed." He adds, "they require long repose and abundance of food to repair the loss of galvanic force expended." This illustrates admirably the parallel between fatigue and enfeebled power of developing electric action.

In the waning power of muscular action resulting from continuous labors of the day, and in the nightly restoration of this power, accumulated during the repose of the muscles, we have the renovation of the exhausted electric excitation that develops vitality.

Some of the lower classes of aquatic animals appear capable of exciting electrical luminosity in a greater or less degree, producing the phosphorescence of the sea, seen most remarkably between the tropics. The excitation from the wheels of an ocean steamer causes a wake so brilliant that it lights up the darkness.

A less intense light is sometimes produced in

shallow water. We have occasionally seen it in Narragansett Bay, gleaming with the dip of the oar, or the paddling with the hand.

The most common source of diffused luminosity is a minute animal, nearly globular, having the appearance of a lump of homogeneous jelly, and provided with a stalk-like appendage. Microscopically, it is found to consist of a sac with definite walls, having its interior — which is for the most part filled with fluid — traversed by a network of a more consistent gelatinous substance, containing numerous cells; the size and form of which are continually undergoing alterations. It has been proved by Dr. Pring, that water containing *noctilucæ*, when subjected to a magneto-electric current, after a time gives out a steady and continued flow of light from the whole of the water; the surface of which appeared spangled with numberless persistent points of light. The light ceases after a quarter of an hour, and cannot be reproduced, evidently in consequence of the death of the animals.

"Of all radiated animals, the *acalephæ* are the most distinguished for luminosity. The light is emitted particularly round the *tentacula*, and from the ciliated surfaces during the movements of the animal; it seems to proceed from a very acrid mucus secreted from the integument.

"The luminosity in many of the marine *annelida* is not a steady glow, but a series of vivid scintil-

lations, strongly resembling those produced by an electric discharge through a tube spotted with tinfoil; lasting but an instant, but capable of being repeatedly excited on irritating the animal.

"In the glow-worm the luminous matter consists of little granules, and is contained in minute sacs covered with a transparent horny lid."

These sacs are mostly composed of a close network of finely divided tracheæ, which also ramify through every part of the granular substance. The lid exhibits a number of flattened surfaces, so contrived as to diffuse light in the most advantageous manner.

That electric currents are excited and transmitted from one part to another of other animals than electric fishes was long ago incontrovertibly demonstrated. The life-power both of plants and animals modifies the transmission of electrodynamic action. All that has been said of the effects of vegetation in producing a disturbance of electric equilibrium will apply equally to the nutritive and other processes of animals. M. du Bois-Reymond, in his researches, has proved that there are no two parts of the body, except those which correspond on the opposite sides, whose electric condition is precisely the same; and that the differences between them are greater, in proportion to the diversity of the vital processes which are taking place in them, and the activity with which these are carried on. Donné says

that the skin and most of the internal membranes are in opposite electrical conditions. It has been found by experiment that galvanism is capable of performing all the functions of the nervous influence in the animal economy.

So numerous are the muscles in certain classes of animals, that it seems indispensably requisite that some general pervading principle, like that of electricity, should act upon them in aggregated numbers, as well as singly. It has been computed that in the animal structure of a single *pentecrinis* of the class of zoöphytes, "there are more than one hundred and fifty thousand bones, each having its appropriate antagonistic muscle. There must be consequently three hundred thousand muscles to be operated on by the will of the animal." [1]

As myriads of frogs' legs might be simultaneously contracted by the transmission of a single electric current through them all, so might this array of muscles be similarly acted upon at once, or in sections, by transmission of electric currents subject to the will of the animal.

By the transmission of a current from electric machines through the motor nerves, art may overcome Nature in controlling animal motive-power, in despite of an opposing will.

Many years ago, while a youthful student of anatomy and physiology, the writer witnessed experiments with galvanic batteries, on the motor

[1] Owen's lecture on Reproduction.

nerves of a human subject, at a time when they attracted great attention from their novelty. The most important nerves were laid bare, and successively subjected to contact with the connecting wires of powerful combined batteries. The transmission of the electric current caused the arm of the subject to be uplifted in a menacing attitude, as when upraised in life to rob a lonely traveller; the fingers to move, and the fist to be clenched. The breast heaved with a convulsive motion, as if laboring heavily in an attempt to breathe.

By forming contacts with different nerves of the face, the muscular contractions exhibited a fitful display of human passions. The eyebrows became alternately arched, and drawn down into a scowl; the nostrils dilated, the mouth contracted, as if tasting powerful acids. Revenge, desire, and loathing were so naturally counterfeited, that it required the stern test of reason and reflection to dispel the illusion that life had been restored; particularly when the eyelid opened with an apparent expression of surprise at being recalled to a world from which he had been expelled with infamy. The electric action was finally transmitted through the extensor muscle of one of the retracted legs; when it became instantly extended, and the foot was thrust violently against the stomach of a curious youth, who was leaning over the table with eager attention. He fainted away on receiving the unexpected kick from a

dead man's foot. Then the experiment ended by applying the battery to revive the muscular action of the impromptu patient. The blow was a startling demonstration of the efficient energy of electric currents in developing animal motive-power, and of the fact that nerves and muscles are electrodes.

It has been suggested by P. M. Roget, that the contraction, or shortening, of the muscles may be the result of the reciprocal attraction which ensues between two portions of conducting matter serving to transmit electric currents in similar directions.

A piece of wire wound in a spiral coil and placed in the circuit of a galvanic current, becomes instantaneously shortened or contracted by the lateral forces exerted between each approximated coil, whenever the electric current is transmitted through it. The discovery, by microscopic observation, of spiral coils in the cells of plants, and also of similar arrangements of the fibres of animal muscles, strongly corroborates this supposition. In Fig. 65 the wire coil is suspended vertically over a glass cup filled with mercury, its lower extremity just dipping into it. The electric

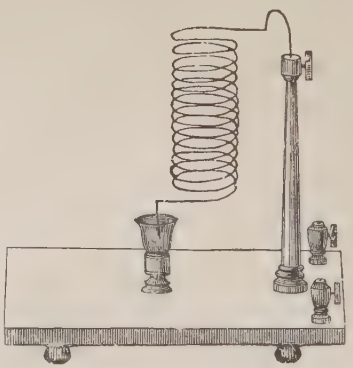

Fig. 65.

current is transmitted from one of the binding cups of the base board, up the brass pillar to the coil and downwards through the coil to the mercury, which is connected by a wire passing out of the bottom of the cup. While the action is transmitted through the coils of the wire, they are severally propelled toward each other, whereby the coil is contracted sufficiently to lift the end of the wire out of the mercury. At the instant this is effected the circuit of the current is broken, and the coil resumes its former length; the lower end of the wire drops down into contact with the mercury again, thus renewing the circuit. This operation being rapidly repeated, the elastic coil is kept quickly vibrating up and down with a peristaltic or churning movement, which is sustained as long as the battery current is transmitted through it.

The peristaltic movement of the intestines during the process of digestion, the intermittent spasmodic contraction of the heart and lungs, and the irregular and occasional contractions of the muscles may be effected in the same manner. As all molecules are current-changers, there is no lack of these perfect little mechanisms to influence the mechanical action of the opening and closing of the valves of the heart. They also change and modify the intensity of the currents and thereby the rapidity and strength of the muscular contractions.

According to Graham's analysis of animal muscle, it appears that the acid phosphate of potash

is an essential salt of the juice of the flesh; and that the alkaline salt of the phosphate of soda is essential to the constitution of blood, to enable it to perform its functions. Hence it has been considered that the probable function of the substances which give acidity to the juice of the flesh and alkalinity to the blood, is the production of electric currents. When we see two substances, one acid and the other alkaline, in opposite negative and positive conditions, separated only by a thin membrane permeable to both (by *endosmose* and *exosmose* action), and in contact with muscle and nervous matter, as observed by Liebig, "we can easily see how electric currents may arise."[1]

The continuous transmission of electric action must be effected by establishing an electric closed circuit.

M. du Bois-Reymond discovered and established the fact that an electric current exists in nerves, the conditions of which are in most respects similar to that of the muscular current. A change in the electric state of muscles takes place in the act of contraction.

Professor Matteucci first made a frog galvanoscope. By means of a battery of ten thighs, he caused a variation of from thirty to forty degrees of the galvanometer needle. From experiments with this instrument, he demonstrated that animal nerves and muscles are electroscopes of the most

[1] Carpenter's Physiology, p. 209.

delicately sensitive character. Were they not carefully covered up within the interior of the body, every contact with metals and other substances, and every change of temperature would induce muscular contractions and convulsions. The sensations of a bared tooth-nerve are too familiar to require description.

The proper electric current of the frog bears this curious analogy to the electric discharges of fishes, — that it is not manifest if the connection be made between corresponding points of the opposite sides; but that it shows itself when the communication is made between points higher or lower in the body, whether on the same or on opposite sides.

A PLANT is a mechanism immediately excited by solar rays to produce groupings of atoms into FOOD and FUEL. An ANIMAL, on the contrary, is a mechanism excited indirectly by the combustion of this fuel. A vigorous man breathes forth from his lungs each day a volume of carbonic-acid gas, which by analysis is found to contain about thirteen ounces of pure carbon. This quantity of carbon is equivalent to an equal weight of pure charcoal burned daily in his lungs, to develop electric excitation constituting animal heat and animal motive-power.[1]

[1] For a minute description of the organs of the eye and of the ear see Helmholtz's profound work on "Sensations of Tone" and "Scientific Lectures," and Leidy's and Sharpey's editions of Quain's Anatomy, with illustrations; also Carpenter's "Comparative Physiology."

CHAPTER XXIV.

LIFE, — OR MUSCULAR AND NERVOUS ACTION DEPENDENT ON ELECTRIC EXCITATION.

HELMHOLTZ thus quotes from Johannes Müller's "Specific Energies of Sense": —

"'The difference in the sensations due to the various senses does not depend upon the actions which excite them, but upon the various nervous arrangements which receive them.'

"According to Thomas Young's hypothesis, there are three kinds of nerve-fibres in the eye with different powers of sensation for feeling red, for feeling green, for feeling violet. In reality, this assumption gives a very simple and perfectly consistent explanation of all the optical phenomena depending on color. And by this means the qualitative differences of the sensations of sight are reduced to differences in the nerves which receive the sensations. For the sensations of each individual fibre of the optic nerve, there remain only the quantitative differences of greater or less irritation.

"The same result is obtained for hearing, by the hypothesis to which the investigation of quality of tone has led us. The qualitative differences

of pitch and quality of tone are reduced to a difference in the fibres of the nerves receiving the sensation, and for each individual fibre of the nerve there remains only the quantitative difference in the amount of excitement."[1]

It would seem, on investigation, that this assumption will give "not only a very simple and perfectly consistent explanation of all optical and auditory phenomena, but also of the phenomena peculiar to each individual organ in the human system."

The organs belonging to the body, the heart, intestines, ear, eye, and brain, &c., as well as the body itself, are individual.

Their individuality consists in the peculiar arrangements by means of which their distinctive functions are performed. There are not only nervous but also muscular arrangements, whose contractility is of vital importance in producing the various motions. The nervous force predominates if delicacy, the muscular if strength, is to be produced. These varying combinations of nerve and muscle are molecular arrangements.

All molecules are electro-magnetic. As the human system is composed of molecules, the body itself and its molecular groupings into distinctive organs must also be electro-magnetic. As each molecule serves as an electric machine for developing a peculiar reaction, so each kind

[1] Helmholtz's Sensations of Tone.

of groupings of molecules similarly serves to develop a peculiar electro-mechanical reaction, which constitutes the characteristic properties of various compound substances.

As before stated, the shapes of crystals are deemed by chemists to be indications of the peculiar kinds of molecules fitting to each other electro-magnetically, according to the angles of their various sides. Some are hexagonal, some polygonal, some rectangular, &c.; each showing their characteristic forms of polarization, the normal condition of each being different. In the formation of crystals we have perhaps a glimpse of the way in which molecular forces work, and of the great power requisite to move them.

With the peculiar organization and form of each kind of molecule there must be, when excited, a consequent peculiarity of vibration; and thus probably are produced the different movements, — as the rhythmic and peristaltic. No doubt, if not beyond the range of future microscopic vision, distinctive movements will be discovered peculiar to the brain, to the eye, to the ear, and to the other organs; and we may yet be able to detect and recognize the different kinds of molecules by the individuality of their vibrations.

Molecules are also machines for modifying, diffusing, and directing electro-mechanical action.

"An electro-magnet is a magnet whose magnetic power subsists during the passage of the

current of a voltaic pile, and ceases when the current is discontinued."[1]

Molecules of one kind are peculiarly arranged in a whorl or vortex (the distinguishing characteristic of the heart), producing when in a state of excitation the rhythmic motion. The less complicated and simple spirals are probably modifications of the intricate whorl, producing a less powerful movement.

It is seen that a portion of the muscular fibres which surround the auriculo-ventricular orifices of the heart are continuous with the segments of the valves, and with the *chordæ tendeneæ*, and through them with the *musculi papillares*, the fibres of which belong chiefly to the innermost layer. As these spiral electrodes ascend internally in a direction opposite to that in which they descend externally, "consequent points or secondary poles"[2] are produced, and the electric current transmitted in one direction would cause the contraction of the *musculi papillares*, thus closing the valves of the heart by making the segments tense; and, transmitted in the other direction, would allow the valves to remain open. "This rhythmic contraction of the muscles is continually and regularly repeated after short and equal intervals of repose." Annular fibres encircle the auricular appendages of the heart

[1] Guillemin's Forces of Nature, p. 16.
[2] *Ibid.* Fig. 422, p. 616.

from end to end, some longitudinal fibres running between them.

In the intestines a peculiar molecular arrangement of nerve and muscle is also found, as well as circular and longitudinal fibres, which are continuous from the *æsophagus* to the *rectum*. This motion of the intestines is called the peristaltic, or churning motion; and without doubt is another manifestation of the periodic impulse.

The eye is protected by a strong membranous covering. The rods and cones are its distinctive molecular arrangement. A single nervous fibril runs from each of these cones through the trunk of the optic nerve to the brain separately from its neighbors, effecting a direct and continuous connection with the brain. As this peculiar molecular arrangement differs from those of the heart and intestines, we may naturally infer that the periodic excitation transmitted to the eye produces there a distinctive motion.

In the ear we find that electric vibrations are gradually changed into currents by the action of the *ossicles*, in passing from the external ear to the brain, and that the connection is continuous. These ossicles in the drum, and Corti's rods and arches in the cochlea, form the peculiar molecular arrangements of the ear; and we may infer that the periods of rhythmic flow and rest penetrate this strange musical gallery, making its chords respond more quickly and sympathetically to the electric vibrations that sweep over them.

"The action of the voltaic current in the organs of the senses in living beings produces precisely the sensations belonging to each of them. By exciting the optic nerves the sensation of light is produced; and that of sound, if the nerves of the ear are touched."[1]

The brain, according to Vauquelin's analysis, is composed of

Albumen	7.0
Fatty matter	4.6
Phosphorus	2.0
Sulphur, salts, and acids	6.4
	20.0
Hydrogen and oxygen in the proportion constituting water	80.0
	100 0

The white substance of the brain and nerves contains nearly seventy-five per cent of water; the gray about eighty-five per cent. The proportion of water is less in the spinal cord, and still less in the nerves.

This analysis shows that water constitutes four-fifths of the human brain; and, as Dr. Hare remarks, "this is the best account it has hitherto pleased God to enable the brain of man to give of its own constitution."

The four principal parts into which the *encephalon* is divided are so intimately connected externally and internally by the white nerve-fibres, — the white substance consisting of tubular fibres and the gray substance consisting of angular,

[1] Guillemin's Forces of Nature, p. 603.

round, oval, or fusiform nerve-cells, — that they constitute but one organ.

From its chemical analysis and molecular arrangements we may assume the distinctive function of the brain to be that of a voltaic battery.

The marvellous convolutions and *sulci*, or furrows, of the brain may serve as leaves of the battery; and they present an extent of surface to the battery fluid which it would be impossible to obtain in any other way.

Thus continuity and intensity of electric action can be effected in a very small space.

The spiral ganglia probably serve as relay batteries. And here again we may conclude that a gentle, modified, and distinctive periodic motion is transmitted through these convolutions in harmony with the heart-beat, keeping the brain as it were on the *qui vive*, a faithful sentinel to the enthroned will of man.

We may assume, then, that the brain is elaborated for the transmission of electric communication to and from itself, and to and from each part of the body; also that this transmission depends on the integrity of the nerves, and ceases with life.

Fluid is essential to a powerful battery current. It predominates in the brain, eye, ear, and various other organs; and in every part of the human body chemical elements and molecular arrangements, requisite for the formation and continuance of a

voltaic battery, are found; and where these exist voltaic electricity will be produced.

Professor Pepper says[1] "that it is a remarkable fact that when an acid and alkaline solution are so placed that their union may be effected through the substance of an animal membrane, or indeed any porous diaphragm, a current of electricity is evolved. Now, with the exception of the stomach and cæcum, the whole extent of the mucous membrane is, in the human subject, bathed with an alkaline mucous fluid, and the external covering of the body — the skin — is as constantly exhaling an acid fluid. The mass of the animal frame is thus placed between the two great envelopes, the one alkaline and the other acid, meeting only at the external outlets. This arrangement has been shown by Donné to be quite competent to the evolution of electricity."

Electric currents are vibrations moving with increased velocity, being more or less rapid as the velocity is accelerated or retarded. Vibrations caused by electric excitation may increase in velocity to a current, and a current decrease in velocity to vibrations and to a state of equilibrium.

In the systemic circulation, the blood is transmitted by the periodic contraction through the whole vascular system. It is conveyed from the

[1] Cyclopædic Science, p. 287.

left ventricle of the heart by arteries and capillaries, and returned by the veins to the opposite and right side of the heart, and again enters the systemic circulation. Beside elasticity, arteries are endowed with a greater or less degree of contractility, by means of which they can narrow their calibre.

"Tonicity, or the tonic state, is no doubt a species of contraction, as well as the more conspicuous and powerful action with which it alternates; but it is employed merely to maintain equilibrium, not to cause motion, — continuing during sleep, when volition is in abeyance, and occasioning no fatigue. When the nerves are cut it ceases, and the muscles become flaccid." [1]

There is also, so to speak, a continuous muscular as well as vascular current, caused by a great number of contractions repeated at very short intervals, and also excited by periodic contraction. Contractions caused by strychnine have been known to follow each other with such rapidity as to disrupt a muscular fibre, showing the marvellous force of molecular action.

Wollaston describes a remarkable sound which is heard when the ear is applied over a muscle during its action. Roget supposed this "susurrus," as he names the sound, was caused by a sort of peristaltic motion of the fibrils. He supposed, also, that the oscillations of the fibrils and

[1] Leidy's Quain, vol. i. p. 328.

the accompanying sound are constant, but that they are greatly increased during the contraction of the muscle.[1]

There is, we may infer, a similar periodic and continuous excitation transmitted through the nerve-fibres, though it may not have been detected on account of the delicacy of the molecular arrangement.

"The cilia, or hair-like processes on the epithelium, execute a lashing motion when not acting very briskly, but when in a state of very rapid excitation their motion is like that of the waving of a field of wheat in the wind, or of swiftly running water. The undulation — or, as it may be, the current — always moves in the same direction in the same parts. The impulse which the cilia communicate to the fluids, or other matter, in contact, maintains a continuity of motion and direction. Thus in the wind-pipe the mucus is conveyed always upward toward the larynx."

We may assume then, from the continuity of this periodic molecular movement (which is always in one direction in the same parts), that the periodic electric excitation, having its prime impulse in the heart, is transmitted in a closed circuit through the vascular, nervous, and muscular systems of the human body; and that the molecular vibration excited in each individual organ is distinctively its own.

[1] Leidy's Quain, vol. i. pp. 226, 227.

By these continuous and all-pervading undulations of the vital current, the friction which must attend the first movement of every molecule of matter, however delicately fashioned, must be prevented, or greatly reduced.

"Some of the voluntary muscles habitually, and all occasionally, act in obedience to other stimuli. Striped (or voluntary) fibre-muscles have been detected in certain parts of the skin, in the hair follicles, in the internal ear, and in parts which are not under the direct control of the will."[1]

The distinction between voluntary and involuntary muscles may perhaps be too sharply defined, if it exists at all. Voluntary motions are effected without any thought of ours as to the way in which they are to be carried out. Were we obliged to choose and regulate the machinery for each voluntary act, our lives would be given up to the work.

"Will simply determines the result, not the special movements by which that result is brought about. The determination of the will is carried into effect through an intermediate mechanism which, without further guidance on our part, selects and combines the particular muscles whose contractions are requisite to produce the desired movement.

"The sensorium or collection of sensory ganglia *plays*, so to speak, upon the cerebrum, send-

[1] Sharpey's Quain.

ing to it sensational changes whereby its peculiar sensation, as an instrument of purely mental operations, is called forth; and in return the cerebrum appears to play downwards upon the motor portion of the automatic apparatus, sending to it volitional impulses which excite its motorial activity. And hence it follows that all the movements which are performed by the instrumentality of the cerebro-spinal nervous system are in themselves *automatic;* and that the peculiarity in their character — whether excitor, motor, consensual, ideational, emotional, or voluntary — is due to the speciality of the source and seat of the impulses which respectively originate them."[1]

We may assume that the continuous periodic motion is one and the same as the continuous automatic movement ready to be "played upon" by the will; and the "speciality of the source and seat of the impulses" to be the distinctive nervous arrangement peculiar to each individual organ.

[1] Carpenter's Comparative Physiology, p. 688.

CHAPTER XXV.

DEATH, — OR CESSATION OF ORGANIC ACTION.

THE cessation of the continuity of the vital current is death, in whatever manner it may be effected. There may be, however, a temporary suspension and renewal of continuity.

"In the human system extinction takes place in the following order," in the circuit of the periodic motion: "It begins in the left ventricle and ends with the left auricle of the heart, — Galen's *ultimum moriens*. After most kinds of slow natural death, the arterial trunks and left side of the heart are found to be almost or even completely empty, and the venous arteries to be full of blood. There are certain kinds of sudden death in which the vitality of the whole system appears to be simultaneously destroyed, and the blood remains in the vessels as it was in the moment of decease." The muscles of man cease to be irritable within a few hours after death.

"There is reason to believe that the sympathetic system constitutes the channel through which the passions and emotions of the mind affect the organic functions; and this especially through its power of regulating the calibre of the arteries.

"We have examples of the influence of these states upon the circulation, in the palpitation of the heart, which is produced by an agitated state of feeling; in the *syncope* or suspension of the heart's action, which sometimes comes on from a sudden shock; in the act of blushing or turning pale, which consists in the dilatation or contraction of the small arteries; and in the sudden increase of the salivary and lachrymal secretion under the influence of particular states of mind.

"In *asphyxia* the deficient supply of arterialized blood to the brain soon paralyzes its functions; and the nervous stimulus (electric current) required for the respiration being withheld, the movements cease. But if the chest be artificially inflated and emptied, and the alternate movements be prolonged, vital action may again be set in motion."

In drowning, the water in the mouth and throat keeps the oxygen of the air from the lungs, producing coagulation of the blood, and consequent cessation of the vital current.

"Kühne maintains that the albuminoid matter of muscle, liquid during life, coagulates after death, and thereby gives rise to the cadaveric rigidity which then invades the muscles.

"If the cessation of respiratory movements results, as when narcotism is induced by poisoning with opium, continuance of vitality may be pro-

longed by artificial respiration,"[1] — as also in drowning.

In death by thirst, the fluids of the body, which are so necessary to the creation of electricity, are exhausted and the whole system tortured while the vital current is gradually arrested.

The excitation of the electric current can be increased by violent passion to such an intensity that disintegration and death will ensue, — as a wire will be disintegrated by a powerful voltaic current. Joy may kill by an intense electro-dynamic action. Fear may produce an electro-static condition, so that the heart ceases to beat. If this condition continues, the power of recuperation is lost, and death ensues.

A blow originates in the will. The result is a small lightning bolt, transmitted over electrodes, impinging against another body. No doubt if the points of contact in the two bodies were visible, we should see the electric fluid passing from one to the other. A diminution and even reversal of its own proper current has been found by M. DuBois Reymond to follow severe injuries of the nerves by mechanical, thermal, or chemical agencies. A sudden blow or shock to the emotional part of our being may arrest the vital current, as well as a blow on the physical frame. Often preceding death the pulse flickers and the ebbing current of life subsides into scattering vibrations, before its final equilibrial rest.

[1] Quain's Anatomy.

"The effect of poison on all animals is death; but dilution delays the effect, and when carried further prevents it altogether; and hence it is probably due to a chemical alteration of the tissue.

"Chemical action or over-action will destroy the living tissues of the body,"[1] and consequently the continuity of the vital electric current.

The most frequent and powerful source of electric disturbance is chemical action; there being probably no instance of chemical union or decomposition in which the electric condition of bodies is not altered. Very many drugs taken into the system produce disintegration or decomposition: the hydrogen in the body, leaving the carbon, unites with the oxygen in the drugs and organic tissues.

In the work of disorganization nitrogen has an active part. Its original name was "azote," a descriptive term, meaning "*against life.*" Its influence in facilitating the separation of the molecules of hydrogen from their union with those of carbon in organic substances has been noticed (p. 180), in relation to prussic acid and other compounds.

The molecules of hydrogen and oxygen composing the blood and flesh of living animals combine to form water, when brought into contact with molecules of nitrogen in nitrate of

[1] Carpenter's Physiology.

silver, and leave the black carbon visible on the surface.[1]

The impregnation of the blood by molecules of nitrogen inhaled into the lungs from decomposing organic substances (of which it constitutes a material part) facilitates a similar union of the hydrogen and oxygen of the blood, in the form of water, with the evolution of "fever-heat." Thus the bile and blood, in cases of yellow fever, are decomposed, and the residuary carbon or charcoal constitutes the "black vomit." In the cholera, a corresponding resolution of the bile and blood into water is manifested by the profuse aqueous secretions, and the dark carbon apparent in the collapsed veins.

The large quantity of nitrogen in pure atmospheric air is combined with just a sufficient quantity of oxygen to develop, by the electro-magnetic union of the latter with the carbon and hydrogen of the blood, the precise temperature of 98° Fahr., marked as "blood-heat."

When the molecules of oxygen are in excess of that proportion, an over-excitation of the human system ensues, — such as is caused by nitrous oxyde, or "laughing-gas." When the molecules

[1] Even light induces the electro-magnetic union of molecules of hydrogen with those of oxygen, in the organic substances of paper and collodion impregnated with molecules of nitrogen, and converts them into water; leaving the carbon, deposited as black charcoal, to form the shades in pictures produced by photographic processes. The excess of nitrogen in yeast is the predisposing cause of the decomposing fermentation of vegetable substances with which it is combined.

of nitrogen are in excess of that proportion, a corresponding depression of the vital powers takes place. Indeed, nitrogen in excess, or free nitrogen from decomposing animal or vegetable substances, constitutes the real miasma, or *malaria*.

Decomposition of all organic substances ceases with a reduction of temperature to that of frost. This, therefore, brings a cessation of yellow fever and other diseases springing from such decomposition.

These molecular actions and reactions in living animal bodies are governed by the universal laws of the planetary forces. When these laws are countervailed from any cause, they produce sickness and disease. The preservation of health depends on a strict obedience to these laws, which regulate the circulation of electric currents through all the conducting nerves. A momentary deficiency or reversal of these currents, — by exposure to a current of cold air, or by a draught of cold water, or an excess of excitation by a draught of alcohol, — may suddenly terminate the existence of a human being on earth.

Whatever may be the apparent cause of death, its real cause is the cessation of the continuity of the vital current.

Then the axial and orbital forces resume their sway, and in death the distinctive organs of the human system are decomposed, and the whole organism is resolved into the carbonic-acid gas, water, and nitrogen of which it mainly consists.

CHAPTER XXVI.

EQUILIBRIUM AND PERIODICITY OF AXIAL AND ORBITAL REVOLUTIONS.

CONNECTED with the diamagnetic current of electro-magnets are consequent polarity, static and dynamic conditions, or states of relative equilibrium and activity. These states or conditions are subject, in the axial and orbital revolutions, to a law of compensating movements.

"If an axial rotation, as well as a horizontal rotation, is communicated by an impulsive force, analysis shows that it may be applied in any plane intersecting the horizontal in the line of nodes; but if applied in the plane of the equator (where it can communicate nothing but an axial rotation), or in the horizontal plane, its intensity must be infinite."[1]

"When the earth is at one or the other of the equinoxes, the plane of the equator prolonged passes precisely through the centre of the sun. The two poles of the planet are then symmetrically placed with regard to the radiant body."[2] This is a static polarity and dynamic diamagnetism.

[1] J. G. Barnard, on the Gyroscope, p. 559.
[2] The Heavens, p. 118. Guillemin.

"Newton showed that if the planets move round the sun describing elliptical curves, according to laws (the discovery of which is due to Kepler), it is because they are submitted to a constant force, located as it were in the sun, — a force the direction of which is that of a radius vector, or a right line, which joins the planet and the common focus."

Is it not possible that the elliptical orbit of the earth may be produced by the (so-called) repulsion of poles of the same name of the sun and earth, propelling them apart in one direction in summer, and the (so-called) attraction of poles of contrary names of the sun and earth propelling them together in another direction in winter?

The apsis line connects the aphelion and perihelion points, and passes through the sun; so that the most direct and powerful repulsion and attraction between the sun and earth occurs at these points.

Kepler's second law is thus stated: "In the motion of a planet around the sun, the radius vector drawn from the centre of the sun to the planet sweeps over equal areas in equal times.

"Every planet moves round the sun with variable velocity, and more rapidly as it approaches the common focus. The earth, therefore, moves less quickly during the summer season of the northern hemisphere than during the winter season."[1]

[1] The Heavens, p. 121. Guillemin.

There is, therefore, in the heavenly bodies varying velocity with compensating axial and orbital movements.

The same laws of magnetic force may be assumed to govern the revolution of the solar system in its vast orbit around some central sun, occupying twenty-six thousand years, as govern the revolution of our earth around its sun. The marvellous magnetic variations and swayings, which seem at present beyond the power of man's calculation and comprehension, may perhaps some day be found to coincide with the magnetic laws of the earth's translation; with the difference in the scale of twenty-six thousand years to one.

All terrestrial matter at rest is under the influence of terrestrial currents. When an overpowering diamagnetic current is induced around distinct molecular groupings, or organisms, they are freed from the earth's directive force, and become electro-magnets.

To render the needle of a lantern galvanometer more sensitive, Professor Mayer neutralized the earth's directive action on it, by means of two large bar-magnets.[1]

Professor Barlow with a battery current around an artificial globe overpowered the terrestrial currents.[2]

" Ampère constructed a static apparatus, — that

[1] A. M. Mayer's The Earth a Great Magnet, p. 266.

[2] Experiment described, p. 99, Fig. 22, *ante*.

is to say, a magnetic system indifferent to the action of the terrestrial globe; then causing a fixed current to act on it, placed horizontally in a direction perpendicular to the magnetic meridian, from east to west, he saw that the action of this current was precisely the same as the action of the earth."[1]

At rest, the gyroscope is a grouping of molecules, or a molecular arrangement. Pre-existing electric currents are present; but, moving in all directions, they neutralize each other. In order to bring the gyroscope into an electro-dynamic condition, a diamagnetic current must be induced around it sufficiently intense to overpower the terrestrial currents. This induction can be effected by whirling the disc, like a humming top, by a string wound round its axis, in which case the impulse will soon be exhausted; or by an electric current, when a relative continuity of action can be obtained, better illustrating the effect of the terrestrial currents. With the battery an artificial current changer is used.

"The law controlling the movements of the gyroscope is as follows: Where a body is acted upon by two systems of forces, tending to produce rotations about two separate axes lying in the same plane, the resultant motion will be rotation about a new axis situated in the same plane between the directions of the other two. It is coincident with

[1] Guillemin's Forces of Nature, p. 612.

the standard point." The disc and all the connected parts of the gyroscope are free to move in any direction.

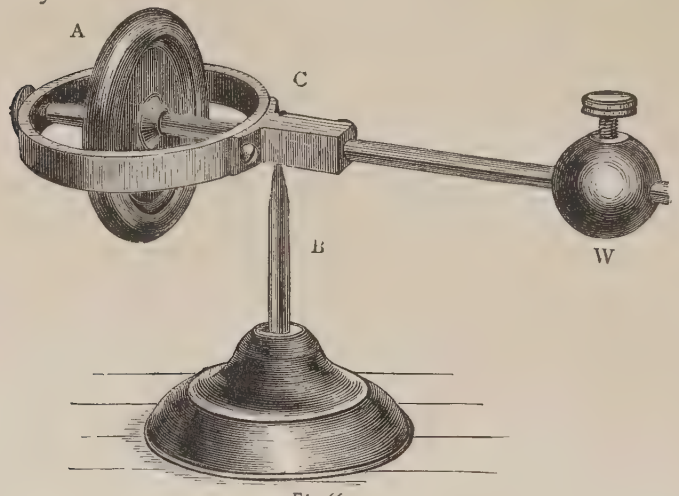

Fig. 66.

If the weight w be placed near the fulcrum c, so as slightly to underbalance the disc, beside rotating rapidly on its axis, it begins a slow orbital revolution in the direction in which the underside of the disc is moving.

By attaching the arm and counterweight so as to balance the disc exactly on the pointed standard, the orbital revolution ceases, while the axial rotation continues till the impulse is exhausted.

By overbalancing the disc, the horizontal revolution is persistently maintained, but changed to an opposite direction, — the direction in which the top of the disc is turning. During the three changes the disc rotates in a constant direction.

In comparing these two electro-magnets, we find that the gyroscope, like the earth, has its diamagnetic current and polarity; its axial and orbital revolutions; its compensating movement and relative static and dynamic conditions; the symmetrical or equilibrial placing of its axis, answering to the earth's equinoctial position when the orbital revolution, of the gyroscope at least, ceases; a declination of the axis when the orbital revolution of the gyroscope is in the same direction as the underside of the disc; and an upward inclination of the axis when the orbital revolution is reversed and is in the direction of the upper side of the disc, answering to the perihelion and aphelion positions.

The rotation of both the earth and the gyroscope is in a constant direction in the three different positions of their axes during their orbital revolutions; and as the gyroscope in opposite positions of its axis moves in opposite directions, may we not infer as a possibility similar movements for the earth?[1]

"Terrestrial analogies afford us a very sure guide in the midst of many perplexities," and the combined movements of the gyroscope fulfil each function as completely as the like movements of

[1] "To say that the equinox falls back, or retrogrades is the same as saying that the plane of the equator has varied in position; and as the axis of the earth is always perpendicular to this plane, it follows that this axis has not remained rigorously parallel to itself." — *The Heavens*, p. 456. *Guillemin.*

the earth; and we may reasonably assume that they are governed by the same laws.

The gyroscope seems to be a working model of all electro-magnets, from the earth to the minutest molecule.

Ampère's theory teaches "that the electric currents, to which magnets owe their properties, are molecular, — that is, they circulate around each particle;" and also, "that magnetic force is in an eminent degree one of circulation." Molecules, therefore, are electro-magnets. The diamagnetic current circulating around each brings with it its train of sequences.

With such power of locomotion, so to speak, in every electro-magnet, there must be even around invisible molecules an invisible or undetected space existing, through which each little molecular orb is rotated and translated; and not only so, but its direction being changed by a more powerful current, it is often transported afar through spaces intervening between molecules varying in size and constitution. They are all like the great earth-magnet, but in miniature.

Reasoning from analogy may we not assume that each rotating molecule, body, and solar system, while perfect and independent in its individual functions, is also in harmony with every other molecule, body, and solar system, — all being governed by the same laws, and together forming a vast, united, and perfect universe?

"In the great basins of the Rocky Mountains, tornadoes will spin rapidly on their axes for a long time, as stationary as a sleeping top." The tornado has then only an axial rotation, like the gyroscope balanced on its standard. If the axis is inclined, it begins an orbital revolution which, in its slowness compared with the velocity of the axial rotation, resembles the gyroscope.

"While the motion of translation of the whirlwind may be only ten miles or so an hour, its whirling (axial) velocity is often a hundred miles or more an hour. They also move in opposite directions. Two of them were seen to whirl within fifty yards of each other at one and the same time, and in opposite directions."

Mr. J. W. Phelps, an eye-witness, describes "a tornado about fifteen feet in diameter, which had several small whirls spinning around on its circumference. The whole system together described a circuit of about one hundred yards across. We watched it from where it set out, until it returned to that point again. It might be compared to a sun with attending planets moving around a common centre."[1]

Herschel's theory is "that a periodical return of heavenly bodies to the same place is the great law of astronomy," as before quoted. The tendency of matter "to move in a straight line," asserts

[1] The quotations are from "Observations in the Rocky Mountains," by J. W. Phelps. 1858-59.

itself only when independent of the circling planets of the solar system; for certain it is, that all the visible matter in the material universe is involved in the general circular whirls from which the descriptive name of "universe" is originally borrowed.

The mechanical action of the revolving heavenly bodies, transmitted as sunshine to the leaves of plants, puts in motion circulating currents of the electric ether and of sap therein; and, by transfer as food, also in living animal organisms. At the instant when the internal circulating currents cease in these subordinate electrical machines, by *death*, the ever-continuing action of the revolving planets, transmitted as sunshine, again predominates over the constituent molecules of the organic bodies of plants and animals.

The sunshine that quickens the formation of vapors into a budding rose, radiant in color and redolent with fragrance, speedily dissolves the gathered rose into vapors that float off in the air. So in the organic formation of man, immediately after the excited currents of electricity and of blood cease to circulate "in the inner sanctuary of life," the vibratory sunshine gradually restores the constituent molecules to their original state of invisible gases, floating in the atmosphere.

Thus, finally, modern science confirms the ancient answer to the question, "What is your

life?" by verifying the fact that it is really "a vapor that appeareth for a little time, and then vanisheth away."

To this boundary line of Physical Science is now traced the final connection between mind and matter, by the electric chain that links together molecules in organisms and solar systems, and holds the whole material universe in subjection to the sceptre of an Immaterial Creator.

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